DEPARTMENT OF THE INTERIOR, CANADA

HON. ARTHUR MEIGHEN, Minister — W. W. CORY, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL OGILVIE, Superintendent

ANNUAL REPORT

OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1920

1919/20

OTTAWA
THOMAS MULVEY
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1921

PRESENTED

WITH THE COMPLIMENTS OF

THE SUPERINTENDENT

GEODETIC SURVEY OF CANADA

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OF THE

GEODETIC SURVEY OF CANADA

W. W. Cory, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

Sir,—I have the honour to submit my report on the operations of the Geodetic Survey of Canada for the fiscal year ending March 31, 1920, together with summaries of the reports of the engineers in charge of the various sections of the work.

TRIANGULATION

INCREASED UTILITY OF TRIANGULATION

The increasing realization of the importance and necessity of the triangulation of the Geodetic Survey of Canada by federal, provincial and municipal authorities, as a basis for mapping, charting and various engineering operations, has been one of the most outstanding and gratifying developments of the more recent work of the Survey. This feature is a good indication of the desire on the part of the Survey for co-operation in eliminating duplication of effort.

This development has been coincident with an increased effort on the part of the Survey to more fully meet the needs of other organizations, by establishing triangulation stations where they can be of the greatest use. The primary triangulation in itself is frequently insufficient to give control points to various surveys where these are most required, since primary stations are of necessity frequently located in out-of-the-way places, and are in general too far apart to serve as a complete control for detailed mapping and charting purposes. This deficiency has been met by the Geodetic Survey by the interpolation of supplementary stations in our primary nets, which not only serve the purpose of being in convenient places themselves, but also aid in locating the positions of many lighthouses, church spires and chimneys whose positions could not be obtained from the primary triangulation stations.

This policy has been very successful through the hearty co-operation of the engineers in charge of all branches of the primary triangulation, those in charge of reconnaissance and direction measurement being especially assiduous in obtaining all the information possible which may be of use to other organizations. This has been particularly noticeable during the past field season along the lower St. Lawrence river, on the upper end of the bay of Fundy and in the Halifax, Montreal and Vancouver vicinities, where the measures for obtaining the positions of the principal lighthouses, many church spires and supplementary stations, were taken in connection with the primary triangulation and the requirements of other surveys and engineering organizations filled at a very small cost.

RÉSUMÉ OF 1919 TRIANGULATION OPERATIONS

Triangulation operations were continued in six provinces—the three maritime provinces, and in Quebec, Ontario and British Columbia.

Nova Scotia.—In Nova Scotia a revision of the reconnaissance for locating stations in the Halifax vicinity was completed and reconnaissance for the main system of triangulation was continued northerly and eastward from Truro, N.S., towards Cape Breton island. Points were located where they would be most useful to control hydrographic surveys along Northumberland strait and Cobequid bay, the eastern end of Prince Edward Island and in the vicinity of New Glasgow, N.S. A report of the engineer in charge commences on page 54.

The measurement of directions of the triangulation was continued eastward by two parties from the vicinity of Amherst, N.S., to Halifax, the reaching of this objective being especially gratifying, as it allowed a final adjustment of the whole Bay of Fundy triangulation, as well as that to Halifax. This permitted final results to be furnished to the Militia Department and the Hydrographic Survey, Department of the Naval Service. Thus the topographic maps of the Militia Department in the Halifax vicinity and the charting operations of the Hydrographic Survey along the Atlantic coast may be placed on the North American Datum. Reports of the engineers in charge of direction measurement begin on pages 48 and 51.

To obtain greater detail in the Halifax vicinity, a secondary triangulation was prosecuted. This scheme gave the position of numerous lighthouses, church spires and other points in the cities of Halifax and Dartmouth and their environs, which will be of great use for the solution of the engineering problems of these cities, as well as providing control points for future re-charting of Halifax harbour. A detailed report of these operations commences on page 44.

New Brunswick.—In New Brunswick reconnaissance for primary triangulation was commenced along the east coast, to connect the Bay of Fundy triangulation with that along the lower St. Lawrence river. This work started from the Westmorland base net near Sackville, N.B. Work was commenced about the middle of July and the triangulation scheme was continued north connecting Prince Edward Island with the mainland. Work was stopped for the fall at Buctouche, Kent county. See page 55 for the report of the engineer in charge.

Quebec.—In the province of Quebec, work was carried on in two sections. In the lower St. Lawrence River district a reconnaissance party and two direction measurement parties operated from Murray Bay to below Pointe des Monts. In addition to the positions of the primary stations, those of all the more important lighthouses and church spires in that area are being determined.

Operations in the lower St. Lawrence district have been vigorously carried on for two years in an effort to complete triangulation control in advance of the charting operations of the Hydrographic Survey. The progress made last season makes us hopeful that next year the Hydrographic Survey can be advised as to the location of our triangulation stations in the vicinity of their work and can thus use these stations for controlling the positions of points on their charts. See detailed reports by the engineers beginning at pages 42 and 49.

The most important and complete example of city triangulation in Canada to date was completed last season in the city of Montreal. Here the accurate positions of many points were established by triangulation to control the accuracy of a topographic survey of the city of Montreal.

Ontario.—In Ontario, the only operations were the completion of the city triangulation in Toronto, which was accomplished by a combination of triangulation and precise traverses.

British Columbia.—In British Columbia the primary triangulation was continued northward between Vancouver island and the mainland and a con-

nection was made to the base line which has been selected near the north end of Vancouver island at Fort Rupert. The triangulation has now been completed from Victoria to the north end of Vancouver island and future primary operations along the coast will be north of this point.

It is to be noted that the datum so far used for the triangulation along the British Columbia coast is provided by the tertiary triangulation of the United States Coast and Geodetic Survey. Thus, while our triangulation has been placed approximately on the North American Datum, the small inaccuracies of this tertiary scheme require that final values of the geographic positions of points along the coast must await the completion of the primary triangulation of the United States Coast and Geodetic Survey from the vicinity of Tacoma, Washington, to the Canadian triangulation in Juan de Fuca strait.

As a basis for engineering schemes of the lower Fraser river, a request was made by the Department of Public Works to the Topographic Section of the Geological Survey and to the Geodetic Survey for co-operation in the mapping of the lower Fraser River district. This scheme was also of great practical value to the city of Vancouver. The work of the Geodetic Survey was the location of control points for the topography of the Geological Survey by means of triangulation and precise levelling. The triangulation was extended from a line of the primary triangulation in the vicinity of Vancouver, the whole scheme being completed during the summer of 1919. For a detailed report of the triangulation in the Vancouver vicinity see page 34. The precise levelling operations are described on pages 9 to 13.

INSTRUMENTS.

The primary triangulation theodolites* used for angular measurements of the Geodetic Survey of Canada are eleven in number—ten 12-inch instruments and one 10-inch (the terms 12-inch and 10-inch refer to the diameter of the horizontal graduated circle). Eight of these theodolites are provided with three micrometer microscopes for reading the horizontal circle, while the other three—including the 10-inch are two-micrometer instruments. The makers of the theodolites are Troughton and Sims (English); Instruments, Limited (English); Bausch and Lomb (American); T. Cooke and Sons (English); Kern and Co. (Swiss) and Wm. Steigel (German). The design of the instruments has been left to the makers with the exception of those made by Cooke and Kern. They vary greatly in design and weight, the latter feature being a determining factor in deciding which theodolites are used in rough country.

Four new Kern theodolites were ordered during the past fiscal year, which will fill the expanding requirements of the Survey for primary triangulation theodolites for some time.

USE OF MOTOR CARS ON TRIANGULATION SURVEYS.

The use of motor trucks and automobiles has more than fulfilled the predictions for economy made a year ago. Two types of machines were used last season: one-ton trucks for the parties measuring horizontal directions and building triangulation towers; and runabouts for reconnaissance and secondary triangulation parties. The experience of last season has brought out several points:—

* For illustrations see pages 13, 16, 20 and 21 of the Annual Report of the Superintendent, Geodetic Survey of Canada, for the fiscal year ending March 31, 1918.

1. Lighter built and less powerful trucks are suitable only in country where the roads are good or fair and the hills not too steep. In country where the triangulation stations are often located in out-of-the-way places on unfrequented roads, and where the roads are only fair and the hills steep, a comparatively light truck with a more powerful engine will be found more economical since the hardships of the roads will produce less strain on the engine.

2. With the light one-ton trucks used last season in Nova Scotia, the running expenses, together with 25% depreciation and interest on the investment, amounted to from 60% to 120% of the average season's expenditure for transport, while the work performed was from 60% to 70% above that of the preceding year. Thus, the cost of occupying each triangulation station was only about 55% of that in 1918. A large part of this showing is attributable to the use of motor trucks, the rest being due to the better weather conditions which existed in 1919.

3. For reconnaissance parties and those doing a great deal of travelling with but little baggage, a light runabout fitted with a delivery box is quite satisfactory and wonderfully economical. In fact in this class of work the greatest saving is shown; the cost of operation of a car, together with 25% depreciation and interest on the investment is less than the amount spent in an average season for travelling expenses and occasional livery and automobile hire, while the party is able to perform from 200% to 300% more work when provided with a car than when they must depend on trains and hired livery for transport.

SUPERVISION OF THE FIELD WORK OF TRIANGULATION.

The field work of the triangulation in Quebec and the Maritime Provinces was carried on under the direction of J. L. Rannie, Supervisor of Triangulation. He organized and directed the operations of all parties working in this part of the country, namely, three reconnaissance parties; four direction measurement parties; two secondary triangulation parties; one tower building party. The field work in this section of the country was well co-ordinated with the result that increased efforts were noted on the part of engineers in charge of parties, to obtain the geographic position of all points essential to those requiring geodetic results.

PRECISE LEVELLING.

During the season precise levelling operations were carried on by five parties—one each in the provinces of Quebec, Ontario, Saskatchewan, Alberta and British Columbia.

The work in the first four provinces was of the ordinary character and consisted in strengthening the precise level net and extending level control into new districts. In British Columbia the work was of a special nature—in the immediate vicinity of Vancouver and New Westminster—and was done in co-operation with the Topographic branch of the Geological Survey, to furnish control for their detail levelling operations. A full description of this work, accompanied by a sketch, will be found on pages 9 and 59.

The mileage of precise levelling, from the inception of the work till the end of the 1919 season, is distributed among the provinces as follows:—

	Miles
Ontario	3,678
Quebec	1,776
British Columbia	1,567
Alberta	1,464
Saskatchewan	1,407
Manitoba	882
New Brunswick	864
Nova Scotia	705
Minnesota, U.S.A.	89

It is distributed among the railways as follows:—

Canadian Pacific Railway	5,193
Canadian National Railways	3,007
Grand Trunk Railway System	2,864
Algoma Central Railway	219
Great Northern Railway	170
Dominion Atlantic Railway	146
Quebec Central Railway	109
Temiscouata Railway	82
Ottawa & New York Railway	55
Pere Marquette Railroad	55
Maine Central Railroad	36
Boston and Maine Railroad	34
Napierville Junction Railway	28
British Columbia Electric Railway	28
Quebec Railway, Light & Power Co.	25
Pacific Great Eastern Railway	9
Highways, etc.	372

This amounts to 12,432 miles and is exclusive of 491 miles levelled in the Yukon in connection with the International Boundary Survey.

The total number of standard bench marks established since the beginning of the Survey is 3,724. In addition, many permanent bench marks of other organizations have been incorporated with the Geodetic Survey's system of levels.

Following out the previous custom a publication was prepared giving provisional results for some 497 miles of levelling and fixing the elevations of 211 permanent bench marks. This publication became available for distribution in July and was circulated widely amongst engineers, surveyors, universities, railway companies, libraries and interested officials of the Dominion and provincial Governments.

Precise Levelling in Vancouver District.

Precise levelling operations of a special nature were carried out in the neighbourhood of Vancouver, B.C., New Westminster and the lower Fraser river valley in the summer of 1919; this work being somewhat outside the usual scope of the levelling operations of the Geodetic Survey, which have been heretofore pretty well confined to trunk lines of levels along the railways.

The Geological Survey, at the request of the Public Works Department of Canada, had undertaken the preparation of a topographic map of the above district, and in order to secure the requisite horizontal and vertical control for their field operations the aid of the Geodetic Survey of Canada was sought. A map was submitted by the Geological Survey showing approximately the lines of levelling required in order to furnish the desired control for the detailed levelling to be done by their field parties.

With one or two minor alterations the program submitted was carried out in its entirety. Mr. N. H. Smith, who has had charge of a precise levelling party for a number of years, was selected to carry on the precise levelling and in the latter part of May he proceeded to the coast and organized a party, engaging such assistance as he required locally and pitching camp on the outskirts of New Westminster.

A few words will be in place here regarding the general lay-out of the work and in this connection the reader is referred to the sketch on page 11. In the year 1914 precise levels had been started by The Geodetic Survey of Canada from the Vancouver mean sea-level datum and carried via the Great Northern railway to Blaine, Wash., at the international boundary and later from Colebrook—a point on this line—to Abbotsford and Matsqui and thence easterly through the mountains. These levels were started at Vancouver from the reference bench-mark of the Tidal and Current Survey, Department of the Naval Service, whose elevation had been fixed by tidal records for seven complete years, between 1902 and 1912. By this means it was possible to base all the precise levelling in the district on an accurately determined mean sea-level datum, the line run in 1914 forming a convenient base upon which to build up much of the new levelling called for. It was decided at the outset that while the more important governing lines must be run both forward and backward, in accordance with standard practice, certain other lines forming loops or connecting links need be run in one direction only. The sketch indicates which lines were done by each method.

The levelling was for convenience subdivided into the following lines:—

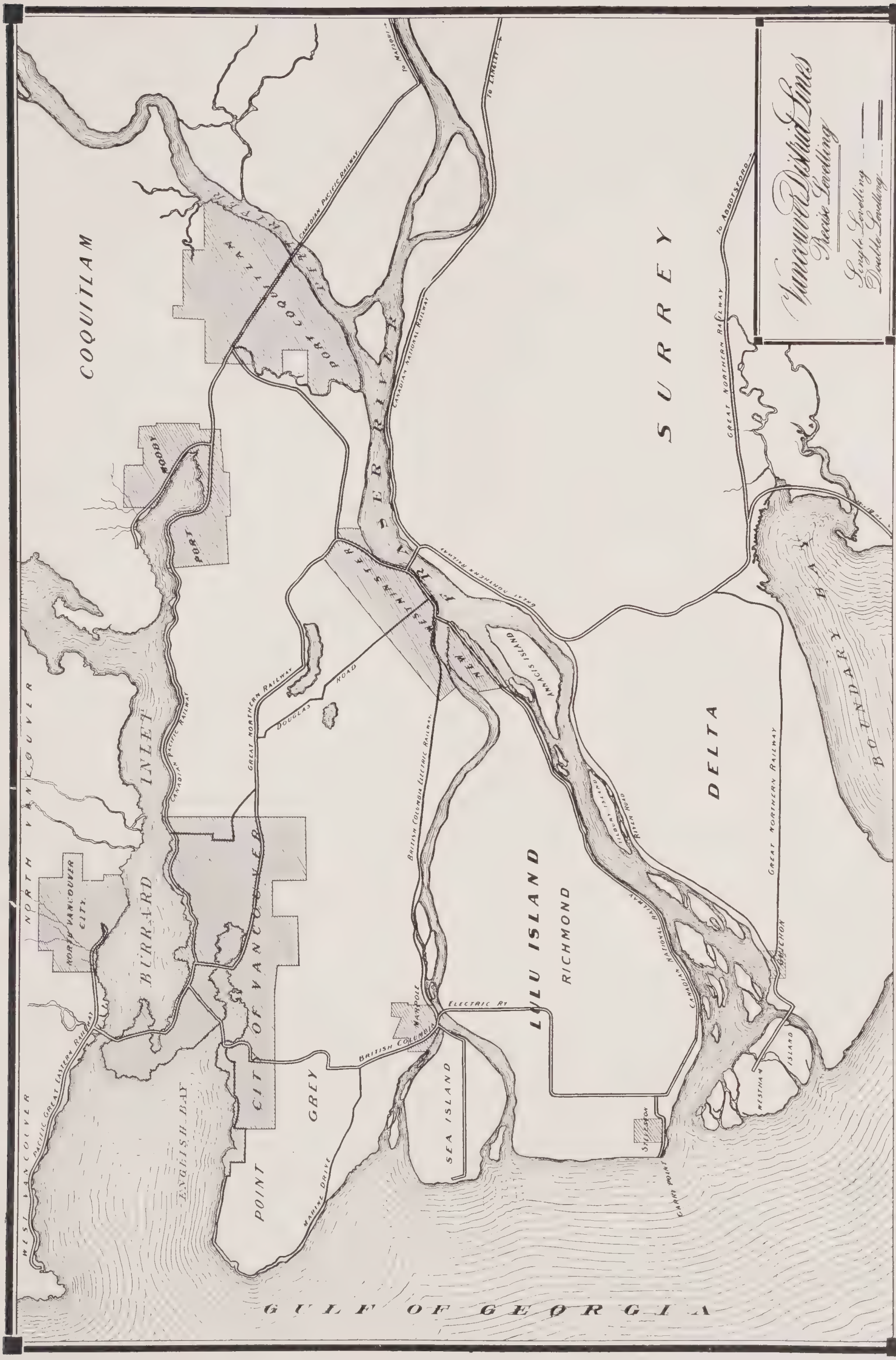
(*a*) Guichon—Ladner loop line
(*b*) New Westminster to Westminster Junction
(*c*) Vancouver to Matsqui
(*d*) Vancouver to Steveston
(*e*) New Westminster to Marpole
(*f*) New Westminster to Steveston
(*g*) New Westminster to Langley
(*h*) Vancouver to Caulfield
(*i*) Point Grey loop-line
(*j*) New Westminster to Second Narrows.

Line (*a*) started from a bench-mark on the Vancouver–Blaine line near Colebrook and followed the Great Northern railway to the village of Guichon, thence through Ladner and along the river road, closing on another bench-mark of the same line with a discrepancy of 0.005 foot—which amount was distributed uniformly along the new line.

Line (*c*) followed the main line of the Canadian Pacific railway from Vancouver to Mission and was then turned southerly along the Huntingdon branch to close on the old levels at Matsqui; the closing error of 0·100 foot at the latter point was distributed at the rate of 0·0023 foot per mile. Line (*b*)—also along the Canadian Pacific railway—was then fitted in, the closure to be disposed of amounting to only 0·003 foot. Both these lines were double-levelled.

Lines (*d*) and (*f*) formed a new connection between Vancouver and New Westminster, the result differing by 0·032 foot from the value obtained in 1914 via the Great Northern. These lines were also double-levelled as it was desired to form an accurate connection between the Vancouver tide gauge and that at Garry Point. The British Columbia Electric railway was followed from Vancouver to Steveston and the Canadian National from there to New Westminster. After disposing of the closing error noted above, line (*e*) was started at New Westminster and run along the British Columbia Electric railway (in one direction only) and closed at Marpole on line (*d*).

Line (*g*) was run as a branch from the Vancouver-Blaine line and followed the Canadian National railway along the south bank of the Fraser river to Langley. It was double-levelled as there was no other available means for checking the line.


Vancouver District Lines
Precise Levelling
Single Levelling
Double Levelling
COQUITLAM
SURREY
DELTA
LULU ISLAND
RICHMOND
SEA ISLAND
POINT GREY
CITY OF VANCOUVER
BURRARD INLET
ENGLISH BAY
NORTH VANCOUVER
NORTH VANCOUVER CITY
WEST VANCOUVER
PORT MOODY
PORT COQUITLAM
NEW WESTMINSTER
FRASER RIVER
ANNACIS ISLAND
WESTHAM ISLAND
BOUNDARY BAY
GULF OF GEORGIA
GREAT NORTHERN RAILWAY
CANADIAN PACIFIC RAILWAY
CANADIAN NATIONAL RAILWAY
BRITISH COLUMBIA ELECTRIC RAILWAY
PACIFIC GREAT EASTERN RAILWAY
DOUGLAS ROAD
MARINE DRIVE
ELECTRIC RY
RIVER ROAD
To ABBOTSFORD
To LANGLEY
To MATSQUI

Line (*h*) was double-levelled for a similar reason. Starting from Vancouver station this line followed the shore of Burrard inlet to Stanley Park and through this to the First Narrows, thence across the Narrows and on to the Pacific Great Eastern railway track at Capilano station. A branch was extended to the city of North Vancouver while the main levels were continued westerly along the track to Caulfield station and down the hillside to Caulfield wharf, where connection was made with another of the tide gauges of the Department of the Naval Service. An unusual feature of this line is the crossing of the First Narrows of Burrard inlet. Even at low tide the distance from shore to shore was found to be about 1,600 feet, which is about three times the maximum length of sight ordinarily taken under good conditions; naturally it was quite a difficult matter to read the rod accurately from one shore to the other. Four determinations were made between a permanent bench-mark near the south shore and one near the north shore, the two extreme results differing by 0·025 foot from the mean of the four. A check on this result was afterwards obtained by one of the Geological Survey parties by means of a water transfer across the Second Narrows and levelling along the north shore to North Vancouver.

Lines (*i*) and (*j*) both consisted of single levelling; the former started from a bench-mark on the Vancouver-Steveston line and extended along the Marine drive to close on another bench-mark of the same line. Line (*j*) started at New Westminster and terminated at a point on the Vancouver-Matsqui line near the second Narrows, following the Douglas road for the major portion of the distance and being checked about midway by the original line along the Great Northern.

In compiling the results the elevations along the two trunk lines run in 1914 were held unchanged and the new levelling was in every case fitted to the old; while a slight gain in accuracy would theoretically have been obtained by an adjustment of all the work in the district—old and new—the difference at any bench-mark would have been so small as to not make up for the inconvenience caused through upsetting the old values which had been given out in published form some years previously. Moreover the field parties of the Geological Survey were working is close co-operation with the Geodetic Survey's levelling party and making use of the provisional results; the course followed above has resulted in these provisional elevations being held in most cases practically unchanged, thereby avoiding the introduction of tedious corrections.

The permanent bench-marks established are of the pattern adopted as standard by the Geodetic Survey for precise levelling work—copper bolts $\frac{3}{4}$-inch in diameter and four inches long, sunk horizontally in rock or masonry or set vertically in the top of a special concrete monument or bench-mark pier. The only departure from standard practice was in the construction of these piers; the usual excavation for same is about six feet in depth, but since the frost is never severe around Vancouver it was considered ample to carry the piers down to a depth of four feet only. As 29 piers were built during the course of the summer's operations a very considerable saving in time resulted. 74 bench-marks were established in all, so it is to be observed that about 40% of the total number had to take the form of specially constructed piers. This is due to the fact that outside the cities of Vancouver and New Westminster buildings with permanent foundations are exceedingly scarce and bridge masonry along the roads or railways is equally scarce except along the Canadian Pacific railway main line. Natural rock suitable for bench-marks was available only in very rare instances. The completed program of levelling included 126 miles of double-running and 56 of single-running or 182 in all, thus making the average space between permanent bench-marks about $2\frac{1}{2}$ miles.

Temporary bench-marks—consisting for the most part of spikes driven into telephone poles or stumps—were established between the permanents for the use of the level men engaged upon detail work.

As mentioned on a previous page a camp was established for the accommodation of the party on the outskirts of New Westminster. Actual levelling operations were commenced at this camp on June 11 and were carried on from there till August 30 when camp was moved to Stanley Park for the balance of the season. Levelling was completed on October 2, the last line to be run being that along the Douglas road, from New Westminster to the Second Narrows. While only a little over ten miles in length this line was an exceptionally difficult one to level over on account of the heavy grades; starting from the Canadian Pacific railway station at an elevation of 13 feet above sea level the levels had to be carried over a hill nearly 400 feet high and then down to the valley of Burnaby lake, about 50 feet above sea level; another hill of 120 feet had to be overcome before the levels were again brought down to sea-level and closed on the bench-mark at the Second Narrows. While this line was the worst one in respect to hills, progress was delayed on one or two of the other lines—notably the Point Grey loop-line—from the same cause. Of the total of 182 miles some 52 miles, or 30%, was run over roads; this in itself caused the work to take considerably longer than would have been the case had railway tracks been available throughout, as levelling along the latter may always be carried out with greater speed and facility. The weather throughout the summer was on the whole quite favourable for levelling.

For purposes of transportation along the railways—going to and from work, moving along from point to point during the day's work, and transporting instruments and material—an ordinary section hand car fitted with a Fairmont four horse-power gasolene engine was used. This was operated over the tracks of the Canadian National, Canadian Pacific, Great Northern and British Columbia Electric railways. However, as a considerable portion of the work lay along roads it was found necessary to supplement this by some other means of transportation. Wagons and teams would have been slow and unsatisfactory and automobile rent was prohibitive in cost, so a second hand Ford car was purchased in Vancouver and sold again at the close of the work. Even though some rather expensive repairs were required during the summer this car proved an excellent investment and was disposed of at the end of the season for not much less than the purchase price. It was especially useful for transporting cement, sand, concrete forms and tools for the construction of bench-mark piers at places inaccessible from any of the railways.

In closing this description of the levelling in Vancouver district the Geodetic Survey wishes to take the opportunity of expressing its thanks to the officials of the city engineer's staff at Vancouver, the Public Works Department of Canada, the Provincial Public Works Department of British Columbia and other engineers at the coast who gave their assistance and co-operation in the prosecution of the work.

LAPLACIAN WORK

In my Annual Report of 1918 and in that of 1919 the unreliability of astronomic observations as a check on the accuracy of topographical surveys was commented upon. This fact is becoming more generally realized and the extent of this unreliability is more generally appreciated. Even for checking up errors in well executed land surveys astronomical determinations are deficient, while any continuance of their establishment for geographic purposes in areas covered by the Geodetic Survey of Canada has no economic value, except in very rare instances.

The subject is so important that I wish to repeat what was said last year in this regard.*

"It may be emphasized that the deviation of the plumb line, an effect which enters directly into all astronomical determinations of geographical positions, is not necessarily nor generally small in value. Two astronomical points on the St. Lawrence, Tadoussac and Father Point, illustrate this clearly. At Tadoussac the vertical leans to the southeast by about 550 feet south and 500 feet east, while that at Father Point leans to the northwest by about 530 feet north and 690 feet west. Astronomical determinations would place Tadoussac 740 feet southeast and Father Point 870 feet northwest, respectively, from their geodetic positions, which would have been a serious cause of error to the Hydrographic Survey of the Department of the Naval Service, which realized the importance of Geodetic Survey work, work free from the deviations of the plumb line." Additional evidence is given by the results recently available at Halifax, N.S., and St. John, N.B., where the astronomic position placed these points 606 feet and 501 feet respectively southwest of their true position.

In this regard also the observations of the late Dr. W. F. King, C.M.G., Chief Astronomer, in his report for the year ending June 30th, 1906, page 3, are significant.

"These astronomical determinations serve a useful purpose in the correction of maps, when the scale of these is not too large. For the control and checking of topographical surveys *they are deficient.* This is due to the fact that the astronomical and geographical co-ordinates of the same point are not necessarily, nor usually, the same. The application of astronomy to topographical purposes proceeds on the assumption that the earth is a true spheroid and that the vertical line at a place (the direction of which it is the part of latitude and longitude observations to determine), is a true normal to it. *This assumption is only approximately true*; the irregularities of the earth, both above and beneath the surface, by their attractions, cause 'local deviations of the plumb line,' so that astronomical positions, though accurate in themselves within a few feet, may show a discrepancy in comparison with survey measurements of very considerable amounts.

Thus astronomical positions are to be used with caution in the control, in testing the accuracy of surveys made with any degree of precision. Their utility has regard rather to general maps, based on a number of local surveys, in controlling compilation. These surveys, each accurate within limits prescribed by its immediate purpose, will yet in general, as experience shows, be subject to errors of scale or distortion. When a general map is compiled by building up these surveys the separate errors tend to accumulate until the aggregate becomes greater than the uncertainty from the cause mentioned of the astronomical observations. In such case these may be applied to correct the compilation.

It has been thought well to emphasize this point, since the relation of astronomical observations to surveys is frequently misunderstood, and corrections often misapplied.

There is still a wide field (1906) for astronomical determinations in Canada, both in correcting general maps compiled from local surveys not co-ordinated, and in affording new points of departure for geographical surveys in unsurveyed regions. *They cannot serve as control for topographical surveys of any degree of minuteness of detail. This is the function of the trigonometrical survey.* (Geodetic Survey)."

*Annual Report of the Superintendent, Geodetic Survey of Canada, 1919, page 8.

The astronomical work of the Geodetic Survey consists only in the occupation of stations about 200 miles apart as combined triangulation, longitude and azimuth stations (Laplace points). Even in such cases, only the *relation* between the resulting longitude and azimuth is utilized and the final geodetic values of the longitude and azimuth at these Laplace stations may bear little likeness to the astronomically observed quantities.

No Laplace points (combined triangulation, longitude and azimuth stations) were required during the field season of 1919. The final results at Halls Hill, N.B. and Klucksiwi, B.C., which were occupied in 1918 are published in the report pertaining to that division of the work.

STANDARDS

The work in the Standards division consisted of a redetermination of the length of the standard nickel metre bar No. 10239 of the Geodetic Survey at Washington, an inter-comparison of the three one-metre bars No. 10239, No. 10241 and No. 10241A and determinations of the lengths of the five invar fifty-meter base line tapes. The three one-metre bars had been standardized at the National Physical Laboratory in England in 1913, and since that time the one-metre nickel bar, No. 10239 has been used continuously in determining the lengths of the base line tapes. The reason of this was that, as No. 10239 was made of nickel, it was considered a more stable bar than either No. 10241, made of an alloy of 46% nickel and 54% steel, or No. 10241A, which is made of invar (36% nickel and 64% steel).

As a result of the intercomparison, which showed some discrepancies, and as the length of the standard nickel bar had not been determined since 1913, since which time it had been in continuous use, it was thought wise to compare No. 10239 with the platinum-irridium metre bar of the United States Bureau of Standards at Washington. A full account of these results is given beginning on page 62.

BASE LINES

The Fort Rupert base line near the north end of Vancouver island, which had been partly cleared during 1918 was cleared of timber, posted and measured duriug the season of 1919. A description of the preparing and measuring of this line is given on pages 56 and 62.

OUTLINE OF CONSTRUCTION WORK

The conclusion of the great war undoubtedly emphasized the importance of the engineer's work and the need of having his work done before emergencies arise.

The war would never have been won if accurate topographic maps had not been procurable; maps not only useful for military purposes, but for all engineering feats along the lines of irrigation, railway construction, canal construction, etc.

As it is well recognized that such maps can only be authentic and reliable if based on a geodetic survey, it naturally follows that the demands on the Geodetic Survey of Canada made by other surveys and corporations are heavy and are increasing from year to year.

During this year in particular the Geodetic Survey of Canada was called upon to give its basic aid to a special mapping survey that was being made of the Fraser river and the city of Vancouver. The Fraser river, as is well known, has

always been full of vagaries in its meandering, but its channels will finally be controlled and dyked thus making it navigable to ocean going vessels. The Geodetic Survey of Canada has made a beginning in this work by running 180 miles of precise levels and by establishing a number of geographic points to be used by the Department of the Naval Service as control for soundings, and by the Geological Survey in making the detail map of the country. Thus an engineering work of national importance is progressing which is founded on results of the Geodetic Survey of Canada.

But in speaking of activities in the West we must not forget to mention those undertaken in the East. The Geodetic Survey of Canada has established a number of triangulation stations below Quebec which have been used by the Department of the Naval Service in its survey of the lower St. Lawrence. These stations are from 15 to 45 miles apart, and are used as a basis by the Hydrographic Survey to control the scale and geographic positions of their charts of the gulf.

The constructive work of the Geodetic Survey of Canada along the bay of Fundy has been extended to Halifax and is thus in a position to be used by the military and naval surveys which are in operation in the interior and along the coast of Nova Scotia. It will also provide excellent control for all the completed or contemplated surveys of the city of Halifax and surrounding towns, for it must be remembered that maps founded on datums other than the North American Datum would most probably clash when meeting. The information offered by the Geodetic Survey of Canada is always enhanced in value by the fact that the North American Datum has been adopted. As an avoider of map clashing the aid of the Geodetic Survey of Canada will always be useful to other surveys and engineers.

It would not be well to forget to say here that the Geodetic Survey of Canada not only has operated over large extents of territory this summer, but has been called upon to serve those parts of Canada where the population is densest, thus assisting in city triangulation work. Particular mention is to be made here of the information furnished this year to the City Engineer of Montreal to provide a control basis for detail mapping of that city.

ADJUSTING OFFICE.

The operations of the adjusting office form a very important link of the chain of geodetic work, involving as they do the inspection and testing of field work to see that it is of the required accuracy, the adjusting and calculations incident upon completed field work, the preparation of data for use by those who require geodetic results and research work for improving the field and office methods.

The requisite structural strength of triangulation nets and the accuracy required in angular, base line and astronomic measurements is of course known to the engineers in charge of field parties, and suitable tests and reductions are made in the field to ensure this accuracy. As the final arbiter of these tests, however, it is the duty of the office to examine results as they are sent in from the field and to advise field engineers when their work has less than the requisite strength.

The adjusting work of the office comprised both triangulation and precise level nets. A first preliminary adjustment of the Geodetic Survey precise levels in Western Canada was made during the past year and much valuable information and experience was gained. Under an agreement of the Levelling Committee of the Department of the Interior, this survey is entrusted with adjustments

of all precise level work carried on in the Department, in pursuance of which agreement the precise levels of the Topographical Surveys branch will shortly be included with those of this Survey in a further adjustment. The combination of the precise level results of these two organizations will enhance the reliability of each and will place level lines in Western Canada on a sure foundation—mean sea-level.

Preliminary and final adjustments of several triangulation nets were completed, or advanced toward completion during the season. These included:

Preliminary......	Bay of Fundy net
	Halifax extension
	Halifax vicinity net
	Lower St. Lawrence River net
	British Columbia net
Final............	Western Ontario (progressed)
	Bay of Fundy net
	Montreal vicinity net
	Halifax extension
	Vancouver vicinity net.

I wish to particularly mention the early publication of a new presentation of geodetic theory by W. M. Tobey, Senior Geodetic Engineer. One of the more immediately applicable of these problems is an improved method of calculating geodetic positions (latitude, longitude and azimuth). Formulae have been developed and tables and forms prepared which have been in use in this office for some time.

A fuller report by the Senior Geodetic Engineer in charge of the adjusting office is given on page 19.

PUBLICATIONS.

That engineers, surveyors, and surveying branches of the Government have been appreciative of the basic nature of the work of the Geodetic Survey of Canada is evidenced by the large number of requests for copies of the various publications now available at this office. Frequently the communications take the form of a request for a complete set to date asking that the name of the firm or person be placed on the mailing list of the institution. The custom of the office is to comply with these requests and it is noticed that the mailing list is steadily growing although it has been revised with much care during the past year. A system is used by which the names of all parties interested in a special line of work are conveniently separated from the main list. Thus the problem of getting the right information to each party is solved. The following is a list of publications available including those that are at the date of writing in the press.

List of Publications of the Geodetic Survey of Canada.

Publication No. 1. Precise Levelling.—Certain Lines In Quebec, Ontario and British Columbia.

Publication No. 2. Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.

Publication No. 3. Standards,—Determination of the Lengths of Invar Base Line Tapes From Standard Nickel Bar No. 10239.

Publication No. 4. Precise Levelling.—Certain Lines in Ontario and Quebec, With Index and Map Showing All Work Previously Published.

Publication No. 5. Field Instructions to Geodetic Engineers in Charge of Direction Measurement on Primary Triangulation.

Publication No. 6. Precise Levelling.—Certain Lines in Manitoba and Saskatchewan, With Index and Map Showing Work Previously Published.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year Ending March 31, 1918.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year Ending March 31, 1919.

With the exception of Publications No. 5 and No. 6, the final proofs of which have been signed to print, copies of all these have been sent out according to the system of distribution mentioned above. In some cases the edition has been nearly exhausted.

THE LIBRARY.

The library contains five hundred volumes and is shelved in 6-unit stacks of leaded glass sectional bookcases in the Superintendent's rooms. The Superintendent's private secretary is responsible for numbering and cataloguing all volumes and periodicals. A special system of cataloguing is employed by which any work is entered under its subject as well as under the name of the author. A member of the staff may consult any work in the library room or may have a volume charged when he has the use of it in his office.

While some of the volumes were published many years ago and are chiefly of historic value many of the leading modern works on geodesy, astronomy physics, mathematics, engineering and topographical mapping are found here. Select books on the subjects just mentioned are added annually with a small list of technical periodicals.

OFFICE SPACE.

The Geodetic Survey building, 980 Carling avenue, which was erected in 1913 to provide office accommodation for the staffs of the Geodetic Survey and the International Boundary Commission was ready for use in 1914 and has been occupied since that date. The development and organization of the Geodetic Survey with the necessary enlargement of the staff have resulted in overtaxing the capacity of the building to a serious degree. To relieve this condition it has been decided to provide office accommodation for the staff of the International Boundary Commission elsewhere. This arrangement will be completed immediately and in a few weeks the entire building will be occupied by the Geodetic Survey. With the floor space thus acquired the crowded condition is relieved and until the continued growth of the Survey again overtaxes the office space a rather serious condition has been removed.

THE CANADIAN GEODETIC SOCIETY.

The Canadian Geodetic Society had its inception in February, 1918, and monthly meetings have been held during two seasons in accordance with the object for which the society was constituted, namely, the advancement of our knowledge of geodesy, topography and allied subjects. The headquarters of the society is at the Geodetic Survey Building, 980 Carling avenue. An enthusiastic interest has been maintained as shown by the large attendance at regular as well as special meetings. Membership is open to persons interested in the work of the society. Meetings are held outside of office hours; members and their friends are invited to attend.

The speaker on every occasion used illustrative slides, many of which are of permanent value. These are available for subsequent use and in this way a library of lantern slides is being started.

A perusal of the following list of lectures given before the society will indicate the usefulness of the society in disseminating the results of specialized study which are extremely desirable to the geodetic engineer whose field of operation covers a wide range of scientific knowledge. Thus members make known to the society the conclusions reached and the source from which they were derived where special investigation has been made.

Lectures Given Before the Canadian Geodetic Society.

Reconnaissance	Mr. L. O. Brown.
The Determination of A Geodetic Datum	Mr. W. M. Tobey.
Side and Angle Equations	Mr. D. J. Fraser.
Service: The Motto of the Geodetic Survey	Mr. J. L. Rannie.
The Fort Rupert Base	Mr. W. M. Dennis.
Aerial Photo-Topography	Mr. H. F. J. Lambart.
The Influence of Laplace Points	Mr. F. A. McDiarmid.
The Canadian and United States Boundary East of the St. Lawrence	Mr. J. A. Pounder.
Survey of A Prehistoric Indian Village	Mr. W. J. Wintemberg.
Field Artillery	Mr. G. S. Raley.
City Triangulation	Mr. A. M. Grant.
Map Production	Mr. J. R. O'Connell.
Precise Levelling	Mr. D. McMillan.
Stereophotogrammetry	Mr. W. C. Murdie.

Special Meetings.

On December 23, 1918, a special meeting was held in the Carnegie Library, when a most interesting address on "Aerial Photography" was given by Lieut.-Col. Cull, D.S.O., of the Royal Canadian Air Service. His Excellency the Governor General and a party from Government House were among the guests, who also included a large number of military officers.

On May 9, 1919, thanks to the enterprise of the council of the society, members and their guests had the pleasure of listening to a most interesting talk on "The Far North" by Dr. V. Stefansson. This meeting was held in the lecture hall of the Collegiate Institute and attracted a larger audience than the auditorium could accommodate.

SUMMARIES OF REPORTS

The following are summaries of reports of the officers in charge of the various sections of the work of the Survey in 1919.

Respectfully submitted,
Noel Ogilvie,
Superintendent.

ADJUSTING OFFICE.

The work of the adjusting office, under the direction of Mr. W. M. Tobey, Senior Geodetic Engineer, is summarized under the following heads:—

1. Field Inspection.
2. Refinement and Correction of Field Data.
3. Progress in the Adjustments (including level adjustment).
4. Determination of the precisions of probable accuracy of sides and other external parts of the triangulation or of a level net as advisory for new field work.
5. Determination of finished data; its necessity for engineers, surveyors and the general public.

1. Field Inspection.

During the year an inspection of the general lay out of the triangulation scheme in the vicinity of Montreal and in the Maritime Provinces was made. The triangulation scheme in the Montreal vicinity was developed from the line Royal–St. Hilaire, see page 27 for diagram. In order to preserve the principle of economics, care was taken not to establish any more stations or measure any more directions than were necessary to establish the required accuracy. Without such care many unnecessary stations and directions would have been used. The sketch on page 26 shows those actually employed to establish the position of secondary points. It is felt that Montreal has obtained a reliable scheme of triangulation which combines strength with as few directions as possible.

The general character of the triangulation in the Maritime Provinces was investigated in the fall, and at the same time plans for the extension of the triangulation work across Northumberland strait to extend the work into Prince Edward Island were gone over. Here, as in Montreal, the desire is to extend our triangulation, using the minimum of figures which will give the required accuracy. As Prince Edward Island is on the border of the Dominion, very little of the triangulation work thereon will be used as a basis for new exterior work; obviously the degree of accuracy obtaining in inland parts of Canada will not be required.

2. Refinement and Correction of Field Data

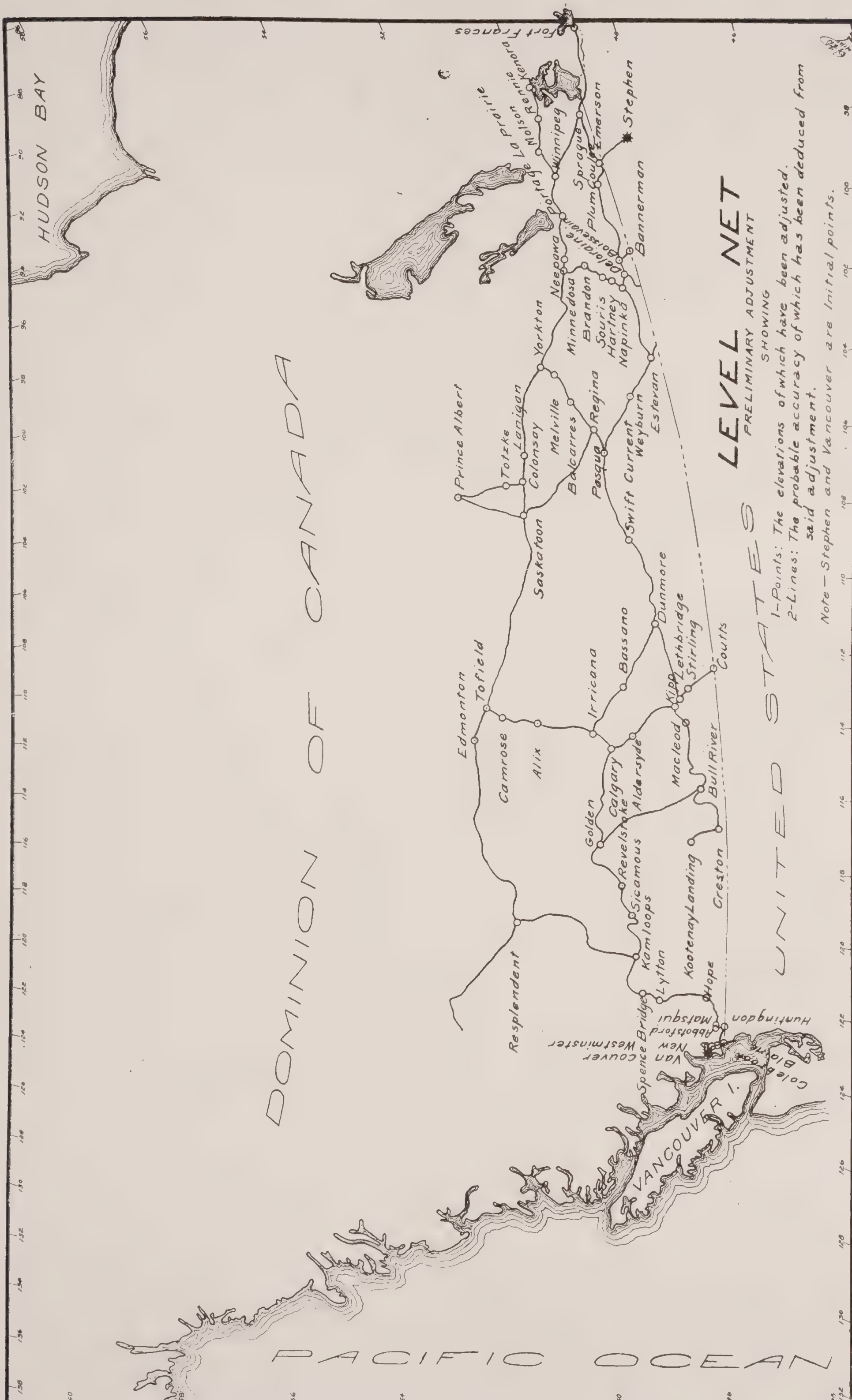
The field operations for the current year which called for much attention by the adjusting office were confined chiefly to the extension of the Bay of Fundy triangulation from the northeasterly end thereof to Halifax (see chart p. 45); the location of a number of points in the vicinity of Halifax for military and hydrographic purposes (see chart p. 48); the measurement of a base at the northwesterly end of the Queen Charlotte-Georgia net in British Columbia, thus with the aid of a Laplace point established in the previous year completing control of that section (see p. 24); extension of the triangulation of the lower St. Lawrence to Father Point (see p. 28); the establishment of a control net for the city of Montreal's topographic maps (see p. 26); the establishment of a secondary net in the vicinity of Vancouver, based on the primary points Little Mountain and West Base which will form a basis for a detailed topographic map to be prepared by the Geological Survey and which will ultimately be of service for many engineering purposes (see p. 39).

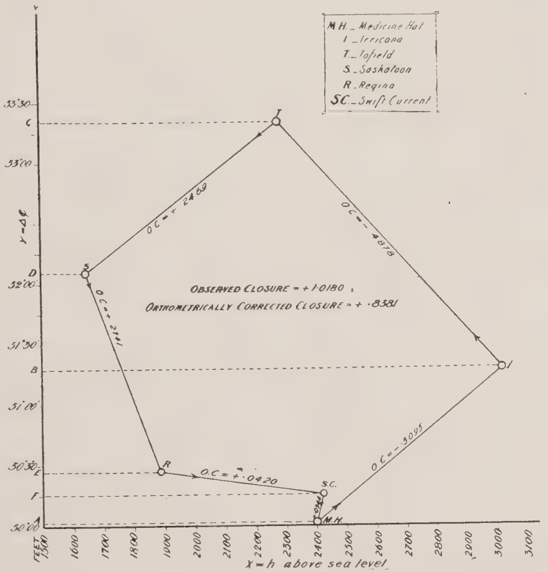
The angle and side equations were tested to see if they were of the required accuracy, the side equation test for primary work being that the average correction given by the adjustment should not be greater than $0{\cdot}4''$. Secondary work was examined by similar methods.

During the year many descriptions of the markings and locations of triangulation stations have been received and revised. These are essential to the public in recovering these stations for their use. It is part of the duty of the cataloguer to see that such descriptions are so filed and indexed with other matter as to be readily available. An indexing of all matter under *name of station* has given excellent results.

3. Progress of the Adjustments

A preliminary adjustment of the precise level net of the Geodetic Survey of Canada from Winnipeg west to the Pacific coast was made (see fig. p. 21). This net, while formerly depending only upon the United States Coast and Geodetic Survey value of the elevation of Stephen, Minn., has now the additional advantage of being controlled by mean sea-level at the tidal station at Vancouver. A tidal station at Prince Rupert will soon be connected to this level net.


LEVEL NET
PRELIMINARY ADJUSTMENT
SHOWING
1-Points: The elevations of which have been adjusted.
2-Lines: The probable accuracy of which has been deduced from said adjustment.
Note—Stephen and Vancouver are Initial points.
DOMINION OF CANADA
UNITED STATES
PACIFIC OCEAN
HUDSON BAY
VANCOUVER I.
Fort Frances
Kenora
Rennie
Molson
La Prairie
Portage
Winnipeg
Sprague
Emerson
Stephen
Plum Coulee
Bannerman
Boissevain
Deloraine
Neepawa
Minnedosa
Brandon
Souris
Hartney
Napinka
Yorkton
Prince Albert
Totzke
Lanigan
Colonsay
Melville
Balcarres
Regina
Pasqua
Swift Current
Weyburn
Estevan
Saskatoon
Dunmore
Lethbridge
Stirling
Coutts
Bassano
Irricana
Kipp
Macleod
Edmonton
Tofield
Camrose
Alix
Calgary
Aldersyde
Bull River
Golden
Revelstoke
Sicamous
Kamloops
Kootenay Landing
Creston
Resplendent
Lytton
Hope
Spence Bridge
Matsqui
Abbotsford
New Westminster
Van Couver
Huntingdon
Cole Bay



Orthometric Correction

Orthometric Correction = $\frac{\sin 2\phi \times h \Delta\phi}{7000c}$ approximately, and hence for sign depends on sign of $\Delta\phi$

Orthometric Correction

Medicine Hat to Irricana = $\frac{\text{AREA OF FIGURE M.H., I., B.A.}}{700000}$ = − ·3095

Irricana to Tofield ...... = $\frac{\text{AREA OF FIGURE I., T., C.B.}}{700000}$ = − ·4878

Tofield to Saskatoon ..... = $\frac{\text{AREA OF FIGURE T., C., D.S.}}{700000}$ = + ·2469

Saskatoon to Regina ..... = $\frac{\text{AREA OF FIGURE S., R., E.D.}}{700000}$ = + ·2741

Regina to Swift Current ... = $\frac{\text{AREA OF FIGURE R., SC., F.E.}}{700000}$ = + ·0420

Swift Current to Medicine Hat = $\frac{\text{AREA OF FIGURE SC., MH., A.F.}}{700000}$ = + ·0514

Orthometric Correction for loop .... = − ·1799

In connection with the above mentioned preliminary adjustment of the precise level net of western Canada several things are to be noticed, namely: the adjusted values of the elevations of points are determined, thus removing discrepancies in these elevations due to the path of approach taken; also the probable accuracy of the elevation of these points and of their difference of elevation is determined. This is the first attempt made to show or indicate the probable accuracy of any given line.

Attention may also be called to the figure on page 22 which gives an illustration of the effect of the orthometric correction on the apparent closure of a level loop. This orthometric correction, based on the fact that the earth is not a sphere but a spheroid, corrects the measured elevations. Without this correction the measured elevation of a point would depend upon the route of approach to that point.

New adjustments of this precise level net, which will include new work, embracing the precise level lines of the Topographical Surveys Branch will not only tend to determine more accurately the elevations of various points, and the relative accuracy of lines over which levels were run, but will also promote uniformity of level results over larger areas by removing clashes and extending the principle of mean sea-level as the datum for level work.

In regard to the adjustment of the triangulation, primary as well as secondary, it is well to mention that a most reliable adjustment is one which contains as many conditions as it is physically possible to handle in one net. While the adjustment of smaller and arbitrary nets will undoubtedly yield values void of clashes and discrepancies, yet their probable accuracy or probable truth is short of that reliability which is based on the adjustment of larger nets. Adjustments of smaller figures or preliminary adjustments are required until sufficient field work is completed to make possible the final or larger adjustment. This final adjustment is made when it becomes necessary to correct cumulative effects of twist in azimuth and discrepancy in scale, as given by Laplace points and measured base lines.

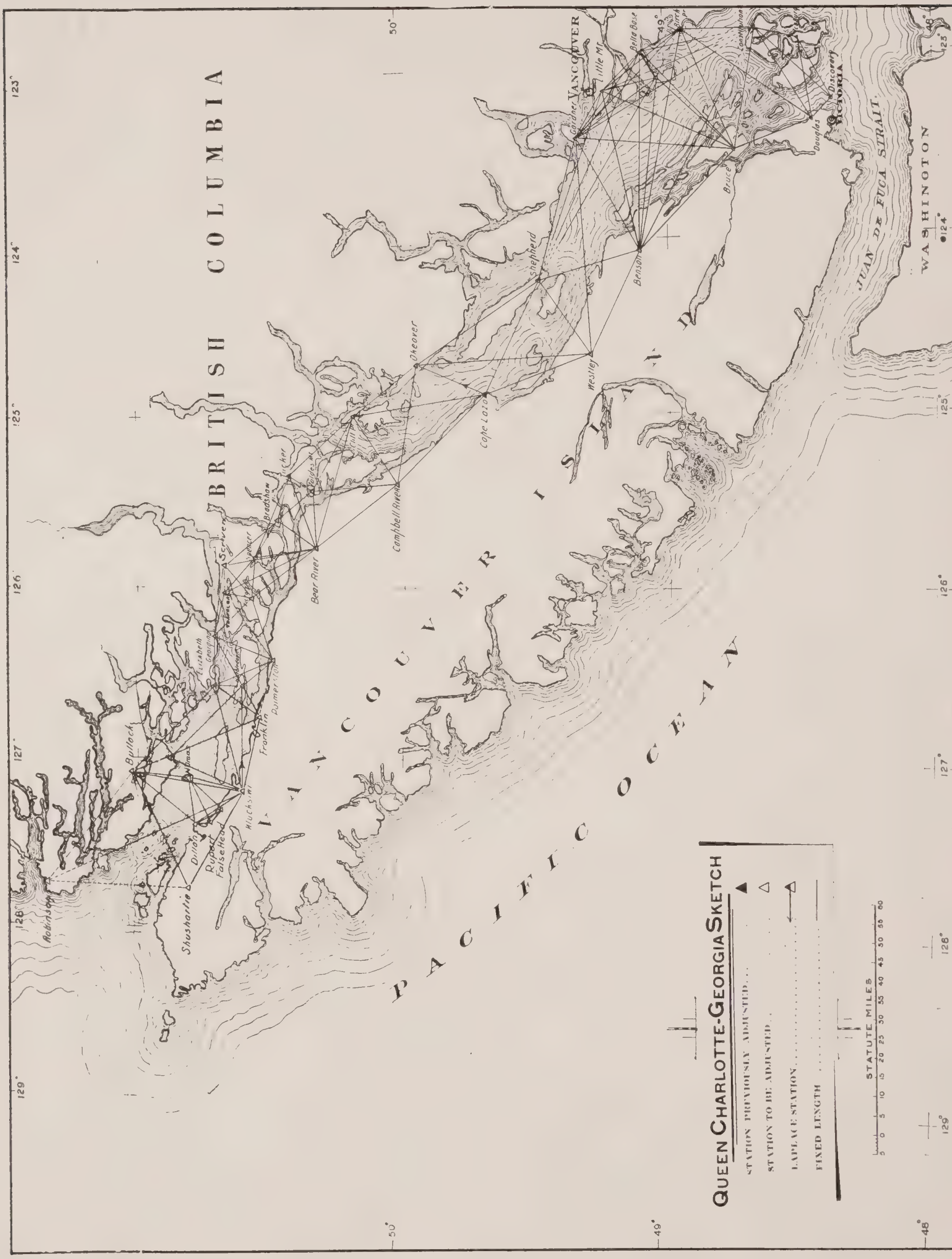
The extension of the Bay of Fundy triangulation from the vicinity of Amherst, N.S., to Halifax was effected by the net illustrated on page 45. This net has been adjusted and is the basis of a smaller secondary net near Halifax, (see p. 48) which enabled the astronomic station at Halifax to be given a geodetic value, free from deviation of the vertical and thus placed on the North American datum. This information is now available for hydrographic and military surveys, whose work in the Halifax vicinity had been based on the above astronomic point at Halifax.

A preliminary adjustment of the angular measurements in the seasons 1918 and 1919 on that important artery of Canada, the St. Lawrence river, has given the position of a series of stations as far down as Father Point. The final values must await the extension of this important triangulation to Anticosti island which will be a matter of two or three years. (See sketch p. 28).

The completion of the field work of the British Columbia net, by the measurement of the base line, False Head to Rupert, now presents an entity of work which allows good values of the geographic positions of stations from Victoria as far as the northern end of Vancouver island. Final values will await the completion of the primary triangulation of the United States Coast and Geodetic Survey, which is being extended from the south to connect with triangulation of the Geodetic Survey of Canada. See page 24 for sketch.

The adjustment of the triangulation around Montreal has given the position of a large number of triangulation stations, church spires and other points which are useful not only to the city of Montreal but to any geographic organization working in the vicinity. See the sketches on pages 26 and 27.

The secondary triangulation net in the vicinity of Vancouver has been adjusted and the position of triangulation and subsidiary points made available for control of the mapping operations of the Geological Survey.


QUEEN CHARLOTTE-GEORGIA SKETCH
STATION PREVIOUSLY ADJUSTED
STATION TO BE ADJUSTED
LAPLACE STATION
FIXED LENGTH
STATUTE MILES
BRITISH COLUMBIA
VANCOUVER ISLAND
PACIFIC OCEAN
WASHINGTON
JUAN DE FUCA STRAIT
VANCOUVER
VICTORIA

4. Determination of the Precisions or Probable Accuracy of Sides and other External Parts of the Triangulation or of a Level Net as Advisory for new Field Work.

This is a subject that always needs the care and attention of the office, since errors of the old triangulation must affect the accuracy of work in progress.

Hence it may be stated in general terms that as a guide for the prosecution of new triangulations, beginning on certain sides of the old triangulation, the probable accuracy of the lengths of such sides should be known, as well as that of other parts of the old triangulation. Only by a knowledge of the probable accuracy of these sides can a decision be made as to the approximate position of base lines in any new triangulation based on the old.

In the adjustment of a precise level net we require to know the accuracy of the elevations of points and of the differences of elevations along certain routes. Remembering that the elevations of points have different values depending on the route taken by the different precise level lines of the Geodetic Survey, the Topographical Surveys Branch and the Public Works Department, it becomes desirable that the most probable accuracy of each line of levels should be known, together with the most probable value of the accuracy of the elevation of the points in question. Only an adjustment based on the mathematical basis of probability and free from preconceived ideas of the accuracy of various lines of levels can give results which will not show arbitrary and conventional handling.

5. Determination of Final Data as Suitable for Engineers, Surveyors and the General Public.

The general determination of finished data free from clashes and incongruities, depends upon a study of the theory of errors, so as to bring about an adjustment of all the data, to give the most reliable values.

It is therefore necessary to do everything possible to *increase* the accuracy of such values. As mentioned above when discussing adjustments this is done by the inclusion of as much of the field data in one net as is possible.

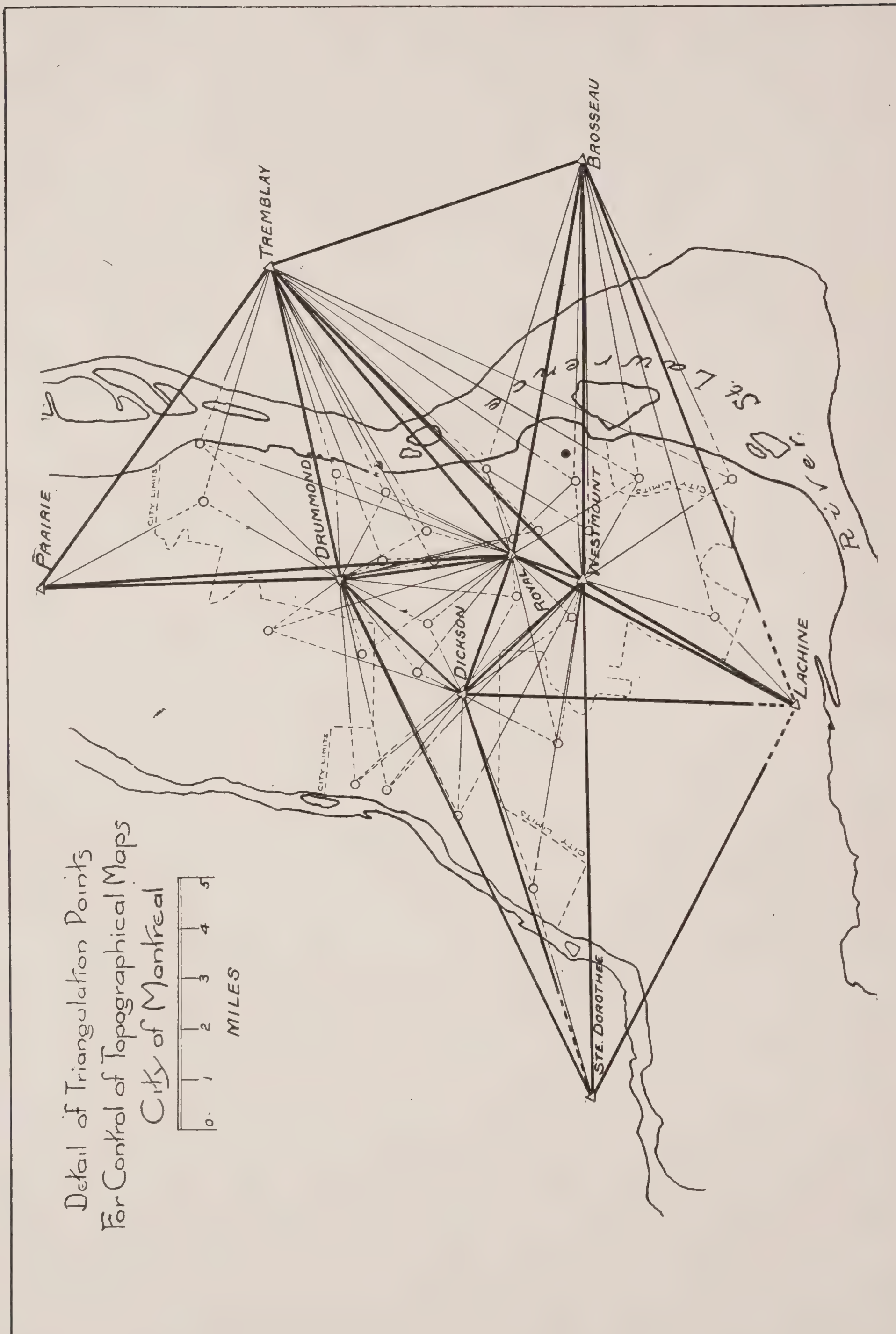
Preliminary results are however generally determined as the field data is secured, in order to meet the demands of those engineers for whom preliminary results are sufficiently accurate.

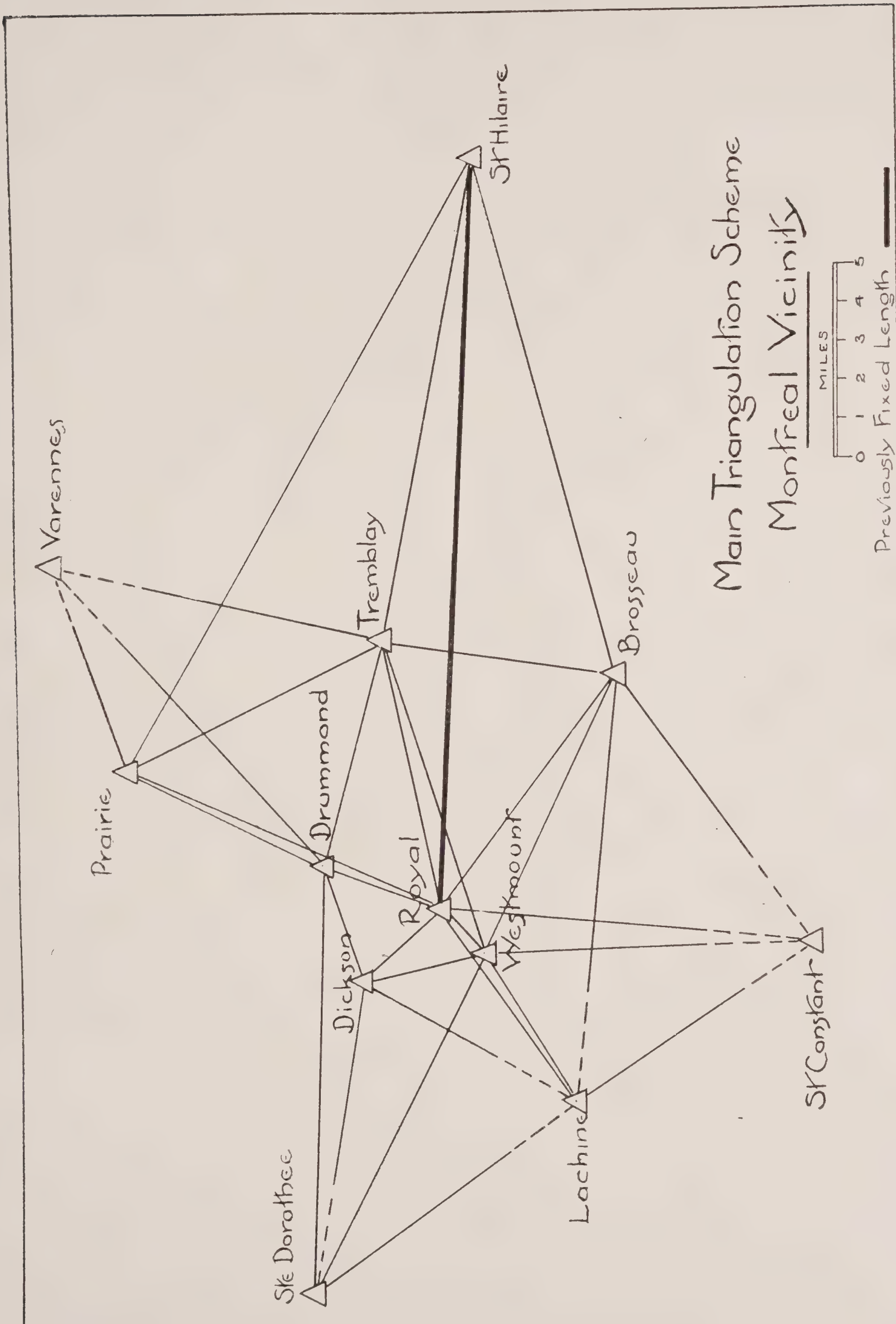
In the case of the precise level net in Western Canada, where one preliminary adjustment has already been made and valuable knowledge concerning elevations and accuracies of points obtained, other preliminary adjustments will be made as new material is available until it can be said that the incorporation of new material has little or no effect upon the old and that the most reliable results have been determined.

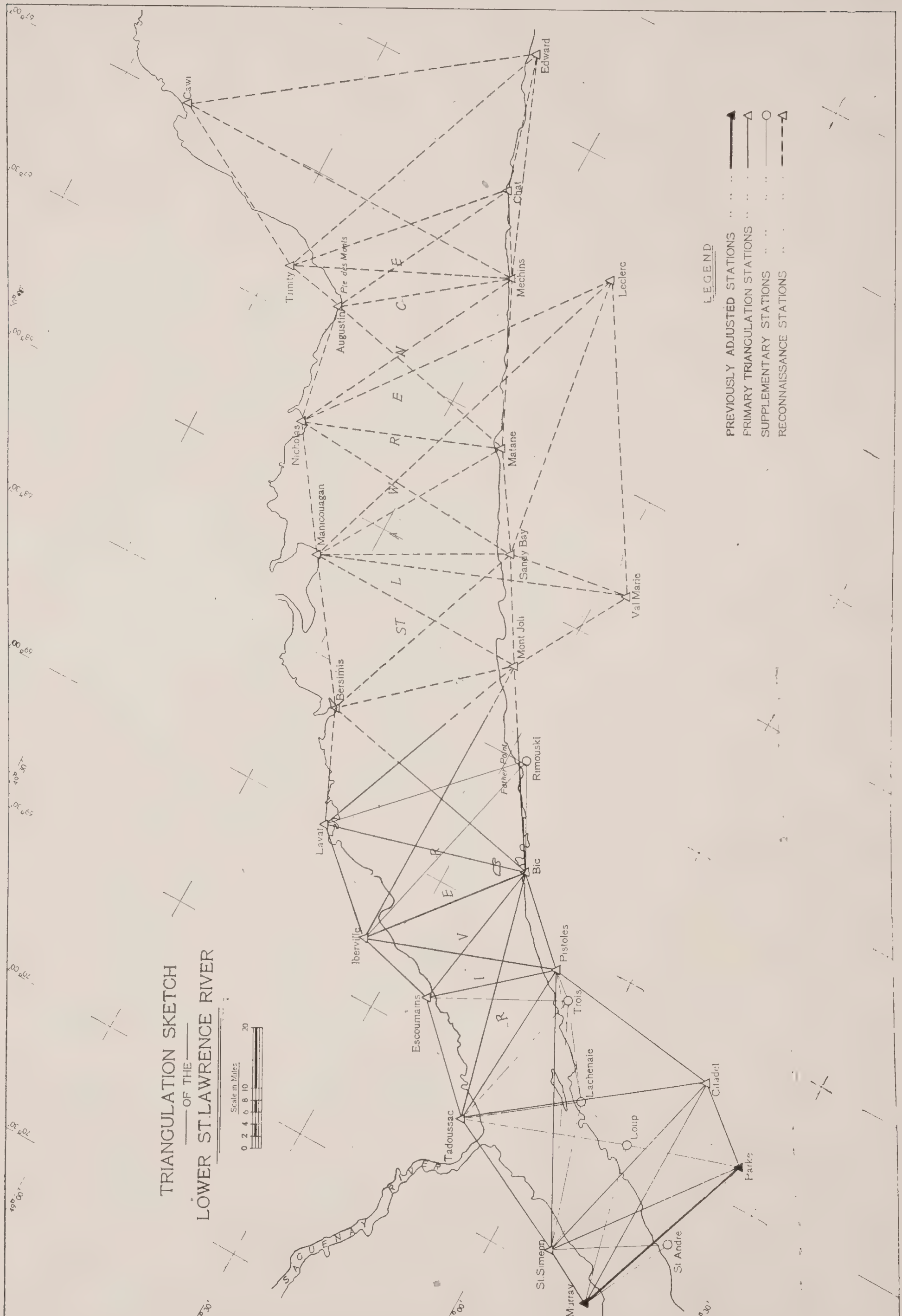
DIVISION OF TOPOGRAPHY.

Douglas H. Nelles, Supervisor of Topography, makes the following report:—

Owing to the members of the staff being absent on military service overseas, and the uncertainty as to when they would report for survey duty, money was not provided for field operations during 1919. Work carried on in the office consisted of calculations and adjustments of various work and the preparing for publication, by the method of photozincography, maps of the Thirtyone Mile Lake watershed and of a strip of country averaging a quarter of a mile wide between the watershed and the city of Hull, covering the location of the proposed pipe line.


Detail of Triangulation Points
For Control of Topographical Maps
City of Montreal
0 1 2 3 4 5
MILES
BROSSEAU
TREMBLAY
PRAIRIE
DRUMMOND
ROYAL
WESTMOUNT
DICKSON
LACHINE
STE. DOROTHEE
CITY LIMITS
St. Lawrence River


Main Triangulation Scheme
Montreal Vicinity
MILES
0 1 2 3 4 5
Previously Fixed Length
St Hilaire
Varennes
Tremblay
Brosseau
Prairie
Drummond
Royal
Westmount
Dickson
St Constant
Lachine
Ste Dorothee


TRIANGULATION SKETCH
OF THE
LOWER ST.LAWRENCE RIVER
Scale in Miles
0 2 4 6 8 10 20
LEGEND
PREVIOUSLY ADJUSTED STATIONS
PRIMARY TRIANGULATION STATIONS
SUPPLEMENTARY STATIONS
RECONNAISSANCE STATIONS
Cawi
Edward
Chat
Mechins
Trinity
Pte des Monts
Augustin
Leclerc
Nicholas
Matane
Manicouagan
Sandy Bay
Val Marie
Mont Joli
Bersimis
Father Point
Rimouski
Laval
Bic
Iberville
Pistoles
Escoumains
Trois
Lachenaie
Tadoussac
Loup
Citadel
Parke
St.Simeon
St Andre
Murray
SAGUENAY RIVER
ST LAWRENCE RIVER
48°30'
48°00'
47°30'

It was the intention of the Dominion Government of 1913 to make a federal district of the cities of Ottawa and Hull and certain districts in their vicinity. With this end in view the "Federal Plan Commission of Ottawa and Hull" was formed to report on a general plan for future development. The commission did its work, made its report in 1915 and disbanded. In 1913 also, the late Sir Alexander Binnie, consulting engineer, and Dr. A. C. Houston, bacteriologist, were engaged to make a report on Ottawa's water problem. Speaking of Thirtyone Mile Lake Dr. Houston says, "The source of supply is unimpeachable on public health grounds, and the water is of excellent quality, physically and chemically. . . It would be difficult to find anywhere a source of supply so perfect in relation to health and freedom from risk of causing epidemic disease. . . A water so pure as to require no purification is almost a priceless boon." Sir Alexander Binnie says, "We would advise you to abandon the Ottawa river and obtain your supply from an uncontaminated source such as is afforded by the lakes lying between the Gatineau and the Lievre rivers. We visited Thirtyone Mile lake and samples were taken which showed that if this water could be secured, the city would be in possession of one of the finest sources of water supply known to us."

"OWING TO THE ABSENCE OF CONTOUR MAPS SHOWING THE LEVELS OF THE VARIOUS LAKES AND THE CONFIGURATION OF THE COUNTRY IT IS IMPOSSIBLE AT THIS TIME TO PREPARE ANY DEFINITE SCHEME OR TO GIVE A PROPER ESTIMATE OF COST. WE WOULD ADVISE, THEREFORE, THAT PROPER SURVEYS SHOULD BE UNDERTAKEN WHICH WILL PERMIT OF DEFINITE CONCLUSIONS BEING ARRIVED AT."

The result of this report was that the Minister of the Interior instructed the Superintendent of the Geodetic Survey of Canada to have the required maps prepared. It was decided to map the lake watershed on a scale of 1–10,000. The watershed contains 109 lakes having a total of 34 square miles of surface. The largest is Thirtyone Mile lake with an area of 18·12 square miles; Pemichangan is 6·5639 square miles; Bois Franc, 0·8502 square mile, and Cipher or Green lake, 0·6853 square mile.

In preparing the topographical map two primary triangulation stations were located near the watershed and on them was based a secondary triangulation scheme of 24 stations covering the area. Tied in to the secondary scheme were 104 topographical stations. Precise levels were run across country from Gracefield to the watershed. The lake shore lines, streams, roads and farm clearings were surveyed by plane-table. The contours of the hills were secured by the method of phototopography, the photographs being taken during February and March, 1914, covering 93 square miles of the south part of the watershed. Large scale detail plans were made of all dam and tunnel sites.

In order to give Sir Alexander Binnie information to figure the cost of a pipe line from the watershed to Ottawa, a topographical map on a scale of 1-2000 was prepared of a strip of country 12·3 square miles in area and averaging a quarter of a mile wide down the Gatineau river valley covering the proposed location. Starting from Intake or Long lake it went straight south to about two miles above Low, where it crossed the Gatineau river at Ramsey's farm and from there followed the Canadian Pacific railway as far as Tenaga, where it strikes across country to the site of the proposed service reservoir just below Pink's lake and from there in a straight line to Hull. These maps show all buildings and other features and have contours at ten-foot intervals.

A separate publication is being got out giving the mathematical results of this survey, but there is certain information about the natural physiography and capabilities of the Thirtyone Mile Lake watershed, in regard to the amount of water available, that should be recorded here.

In order to make sure that there was enough water available, from this and adjoining sources, for all possible needs in the future, preliminary surveys were made of two connections with other watersheds, to see if they could be joined up with that of Thirtyone Mile lake.

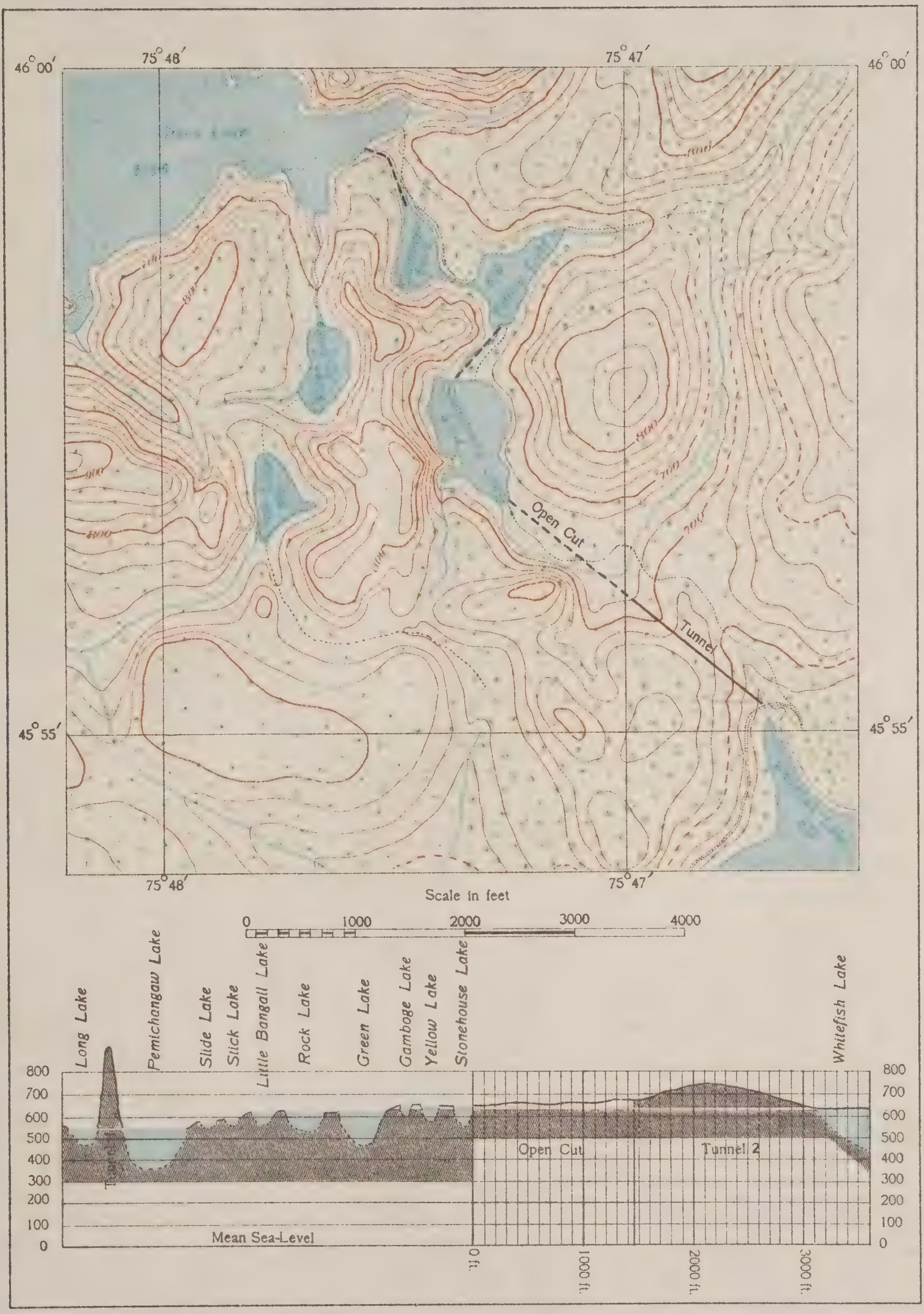
The first of these connections is from Whitefish Lake watershed and is shown on the opposite page, as "Tunnel 2." There would be about 1,500 feet of tunnel and about 3,200 feet of open-cut. The length of tunnel 2, and the depth of the open-cut connected with it depends upon the height to which the water of Whitefish lake is raised by dam 4, at its outlet. The cost of this connection depends, therefore, upon the economic balance between the cost of the tunnel and open-cut, and the cost of dam 4.

If more water than that mentioned in the above paragraph were needed, it could be very cheaply obtained by building a small dam across the Lievre river just below the entrance to Whitefish Lake creek, marked dam 3, plan on opposite page. The details of this dam site are shown on plan page 32. It will be seen that the difference of elevation between Whitefish lake and the Lievre river is only 11·1 feet, so that a very small dam would be all that would be necessary; in fact the Lievre backs up into Whitefish lake during the high-water period.

All of the topographical survey of Thirtyone Mile Lake watershed is finished with the exception of the contours of the hills of the north half of the area. As the country is heavily wooded, phototopography by the ordinary intersection method is rendered difficult by the inability to recognize control points. During the summer of 1920 a small party is being sent out to this area under Professor G. R. Anderson, of the University of Toronto, to do some experimental and research work, with a Stereophotogrammetric surveying camera. With this camera a base of from 50 to 300 feet is used, so that the identification of points of control is absolute.

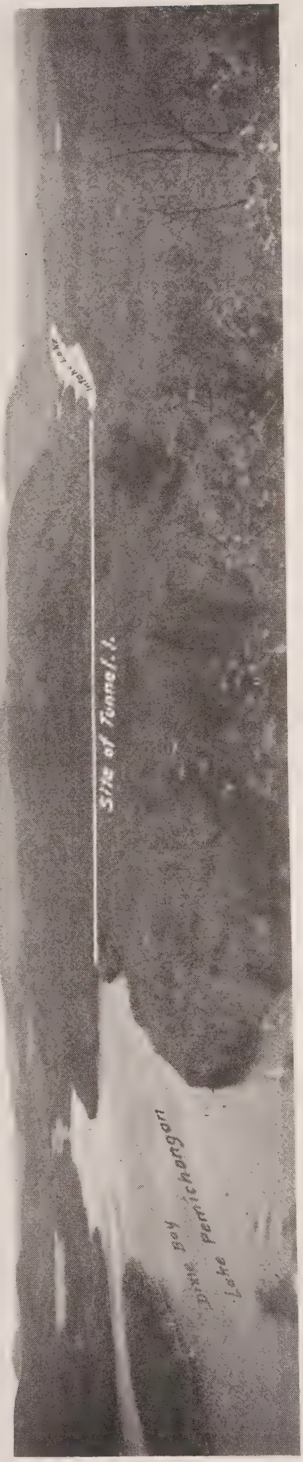
A request was received from the mayor of London, Ont., that the Geodetic Survey undertake the making of a large scale topographical map of the city and vicinity, based on a complete triangulation net covering the area, a net of precise levels and a system of traverse and secondary levels upon which to hang the details for a large scale city map such as described in the superintendent's report for 1919, page 29. An agreement, has been made between the Geodetic Survey and the city of London for a complete topographical survey of that city.

This is the initiation of a policy of systematic mapping of Canadian cities and towns, similar in many respects to that of the function performed by the Ordnance Survey of Great Britain, which surveyed the triangulation and precise level net of Great Britain and Ireland and made large scale maps of all the cities and towns. The tremendous value of these maps cannot be estimated in dollars and cents. Canada is today just at the critical turning point in her history when she has awakened to the fact that it is not good policy to let the slum conditions that exist in Europe grow up in Canada. Our cities are small and are not yet of metropolitan size and in most of them town planning commissions have been formed. The function of a town planning commission is to so guide the growth of a city that it shall be healthy and beautiful and its transportation arrangements such that business can be conducted in the most efficient manner. Large scale city maps are the basis from which plans are designed for orderly development. They are not only used by planning commissions and municipal engineering departments, but are used by electric, gas, telephone, telegraph and electric railway corporations, insurance companies, real estate men, surveyors, engineers in private practice and other individuals They directly affect all classes of the community.

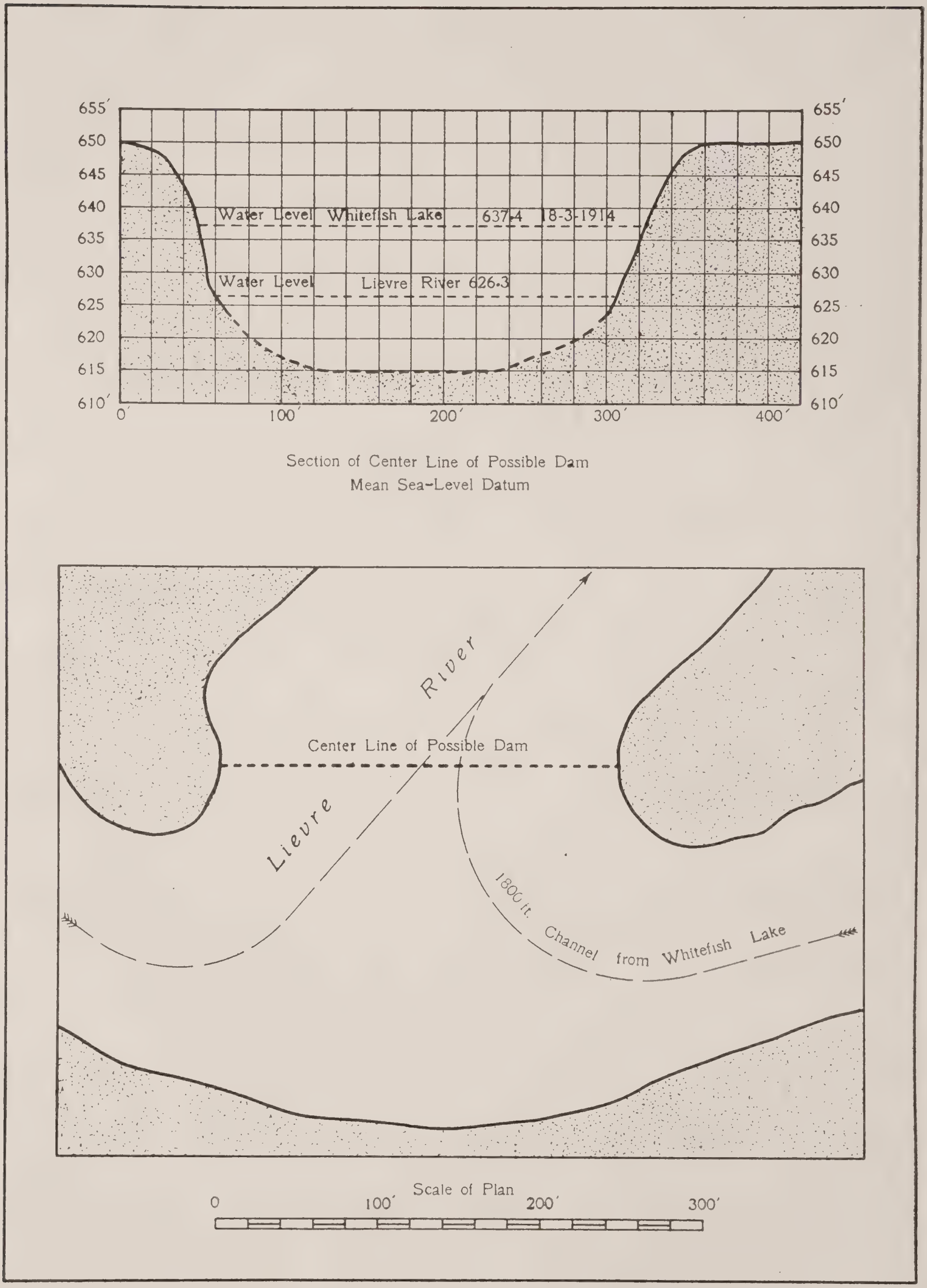


Map & Profile Showing Possible Connection Between Whitefish & Pemichangaw Lake Watersheds.

Site of Tunnel 2. View from Station "Wing" looking South and West. Whitefish Lake is on the extreme left.



Site of Tunnel 1. View from Station "Legg" looking South toward Ottawa.



Plan and Profile of a possible site for a Dam on the Lievre River to turn a portion of its water into Whitefish Lake.

PROGRESS REPORTED ON THE BRITISH COLUMBIA COAST NET

W. M. Dennis, Geodetic Engineer, reports as follows on the work carried out by this Survey, on the British Columbia Coast Net.

A party was organized, and arrived at Fort Rupert, the base of operations, about six weeks earlier than in previous years. In this district, southeast of Queen Charlotte sound, this period of the year proved far more satisfactory for observing, so this part of the work was pushed as rapidly as possible. Concerning this, see Mr. MacTavish's report page 34.

Vistas were required on eight stations and two intervening islands. With the number of men at our disposal it was found difficult, on account of the heavy timber encountered, to keep this work in advance of the observers.

On July 25, on account of the fog, which at that season of the year comes in off Queen Charlotte sound, observation of angles was discontinued, the party was materially reduced, and work on the preparation of the Fort Rupert base was taken up. During the latter part of 1918 this base had been located and the timber cut out, but much work remained to be done, as logs, stumps and small hillocks had to be removed throughout its full length, approximately six miles. In this work, dynamite was found to be most economical and one quarter of a ton of this explosive was used.

Posting was carried out in conjunction with the clearing of the line. As much scaffolding and crib-work was necessary around the higher posts, stumps and fallen logs, instead of being removed, could often be used as foundations to work from, and thus much time was saved in preparing a stand and support for the straining bars.

Posts split from dry cedar, obtained close at hand, proved very satisfactory. They were quickly sharpened, drove well and did not check in the sun. The posts were light and the distance they were carried when distributing them, was short.

Before beginning the levels, an attachment was made for the rod, by means of which it could be hung from the top of the post, part of it extending down the side of the post. This was necessary because of the height of a large number of the posts, and the difficulty of obtaining solid supports for the tripod legs. The surface of the earth was composed of moss, decomposed wood and fibrous roots, and a set-up could seldom be obtained in its natural location, along the line. When solid support for the instrument could be found, the posts in its vicinity were generally higher than the instrument, but with the aid of the attachment referred to above, a negative reading was obtained and entered as an intermediate sight. It was necessary to have a plumb line attached to the rod when using this attachment, as the point of support was about two and a half inches off the line of the rod graduations.

Double turning points were used as a check throughout the length of the line. A side spur was run down the Keough river and a copper bolt placed in the rock on the right bank at about the level of a 24-foot tide.

The Fort Rupert end of the base is marked by a copper bolt, leaded into an outcrop of bed-rock. At the False Head end, a gravel bed underlies the surface at a depth of about 2 feet. A slab of concrete 4 feet by 4 feet by 14 inches was placed $4\frac{1}{2}$ feet below the surface, and a shaft 12 inches by 12 inches carried to the surface. In the top of this the copper bolt was set.

During the season, in transporting men and materials, the launch "Metra" was run approximately 6,000 miles, without accident. This coast is very hazardous on account of the pinnacles of rock that approach the surface of the sea in the most unexpected places. After July, heavy fogs are prevalent and as the coast, in the vicinity of our work, is a maze of small islands and channels, navigation of a boat drawing even 6 feet of water, is no sinecure, particularly when the greater part of the running is done off the main lines of traffic, where the charts are still incomplete.

The chief difficulty in the measurement of this base was in the care of the tapes when moving along the line. However, the work was accomplished without accident or injury to them.

The agreement between the measurements of each kilometer obtained with the different tapes, was very good. On the third kilometre this difference was 3.753 mm. On the fifth it was 2.042 mm., on the first 1.04 mm. and on the remaining 7 it was less than 1 mm.

Summary of Results.—Primary triangulation: 800 square miles of area covered; 10 stations occupied for horizontal and vertical measures; 8 observing tripods built, 2 observing towers built; 6 copper bolts and 1 cement pier set, and 6½ miles of vistas cut. Primary base, 9.6 kilos long, cleared of logs, stumps, etc., posted, measured, and levels taken.

DIRECTION MEASUREMENT ALONG THE BRITISH COLUMBIA COAST

W. H. Mactavish, Geodetic Engineer, submits the following report on the observing which was carried on along the British Columbia coast during the field season 1919.

The field of operations was in the vicinity of Alert bay at the northerly end of Vancouver island. Observing was begun about the middle of May by two observers: Mr. C. A. McGillivray and the writer. The lightkeepers at each station were equipped with two lights, which were placed one above the other over the station mark and pointed to the stations occupied by the observers. The observers, too, served as lightkeepers for each other. It was the experience of the observers that the lights used by them had to be placed at least five or six feet below the line of sight of the telescope, in order that the heat waves from the lights should not interfere with the observing.

Weather conditions were as satisfactory as might be expected. Considerable rain fell during the first part of the season but not sufficient to materially hinder the progress of the work. In the vicinity of the past season's work, fog is the chief obstacle with which observers have to contend. It is probably more prevalent during the month of August than during any other month.

On account of the personnel of the party having to be cut down early in the season, observing was discontinued after the end of July. During the season ten primary stations were occupied. Two of these were reoccupied. Pulteney Point lighthouse was cut in from two primary stations. Early termination of the observing permitted of the lighthouses on Masterman and Pine islands being observed on from only one station. The following stations were occupied: North Base, South Base, Bullock, Dillon, Klucksiwi, Numas, Elizabeth, Franklin, Harbledown, and Palmerston.

Considerable difficulty was found in measuring the angle adjacent to the base line from the north end of the same. It was on a night following a very hot day that the angle was first measured. The light at the south end of the base line appeared very unsteady and difficult to point on during the reading

The gradient of some of the 100-metre sections was fairly steep.

Note the effect of dynamite where there is not room to use either saws or axes.

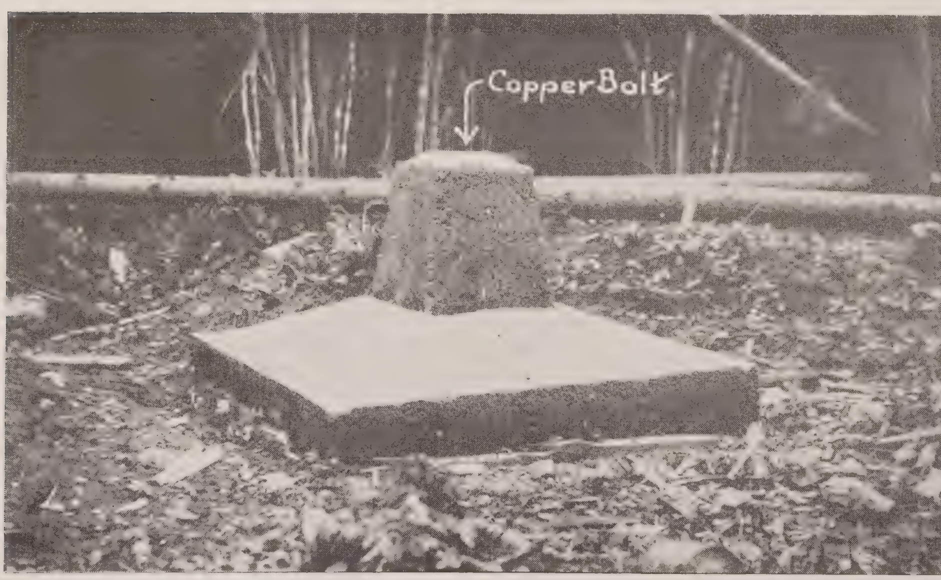
FORT RUPERT BASE LINE.

Fort Rupert Base Line.—As much scaffolding and crib work were necessary around the higher posts, stumps and fallen logs, instead of being removed, were often used as foundations in preparing a stand and support for the straining bar.

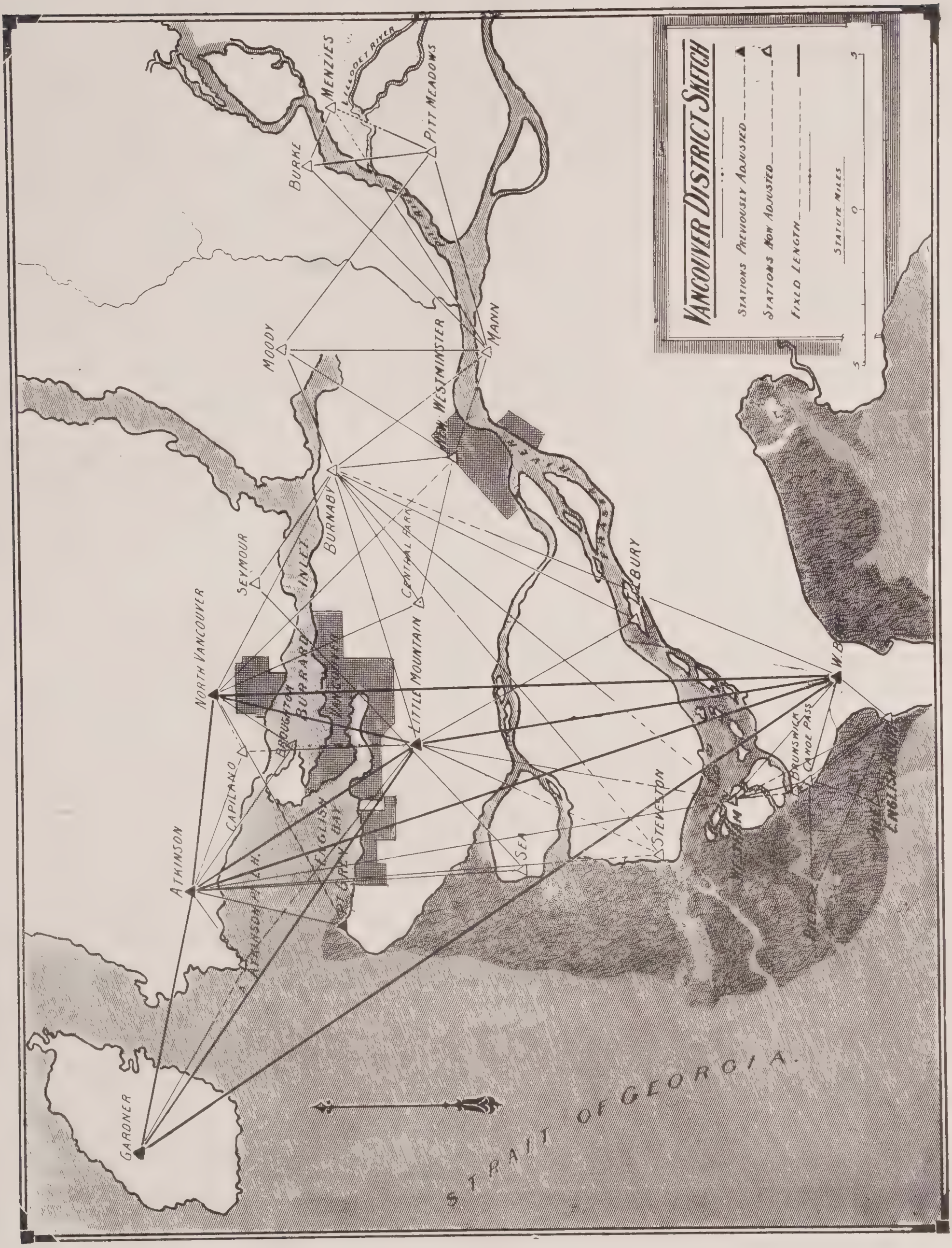
Fort Rupert Base Line.—The chief difficulty in the measurement of this base was in the care of the tapes when moving along the line.

FORT RUPERT BASE LINE.—Posts are all independent of the crib-work around them and braced in two directions where necessary.

Fort Rupert Base Line.—On part of the line the timber was blown down by wind storms. See in the foreground, two axes, held by men standing full height on logs above the ground.



Concrete monument used to mark Triangulation Stations where the presence of bush and underbrush makes recovery of the station difficult. (This photograph was taken before the monument was surfaced with cement).


VANCOUVER DISTRICT SKETCH
STATIONS PREVIOUSLY ADJUSTED
STATIONS NOW ADJUSTED
FIXED LENGTH
STATUTE MILES
5
0
5
MENZIES
PITT MEADOWS
BURKE
MANN
MOODY
NEW WESTMINSTER
BURNABY
SEYMOUR
CENTRAL PARK
NORTH VANCOUVER
LITTLE MOUNTAIN
VANCOUVER
BURRARD INLET
CAPILANO
ATKINSON
ENGLISH BAY
SEA
STEVESTON
BRUNSWICK
CANOE PASS
STRAIT OF GEORGIA

of the first eight or ten positions. During the latter part of the night, when the temperature along the line had decreased sufficiently, the light appeared as it would under ideal observing conditions. The first eight positions, while consistent, gave a mean of 56.83 seconds. The mean of the second half was 59.47 seconds—a difference of 2.64 seconds. Were the results of only the last eight positions taken, a good closure would be effected for the triangle adjacent to the base line; but when all sixteen positions are considered, the triangle is in error about two seconds. Attempts, later on, were made to remeasure this angle, but refraction on the line was so great that no reliable results were obtained. This angle will have to be measured on a night following a cloudy or rainy day when the temperature along the base line will be more or less constant.

From an economical standpoint, observing along the southern British Columbia coast should be begun as early in the season as weather conditions will permit. As the season advances, considerable time is lost on account of fog. It is well within the margin of safety to state, that in the vicinity immediately to the south of Queen Charlotte sound fifty per cent more work can be accomplished during the month of May than during either the month of August or September.

TRIANGULATION OF THE CITY OF MONTREAL

A. M. Grant, Geodetic Engineer, reports as follows on the triangulation of the city of Montreal, and surrounding district, carried out by the Geodetic Survey of Canada during the season of 1919.

The engineers of the city of Montreal had long felt the necessity for a complete new map of the territory embraced within the limits of the city, as well as that of the adjoining municipalities which in the near future, are likely to be annexed by Montreal.

As the first requisite of such a map is triangulation control, the Geodetic Survey of Canada was asked if control could be furnished, from the primary triangulation points in that section of the province of Quebec. As a secondary triangulation scheme would locate a great number of geographical positions in the district within forty or fifty miles from the city, an agreement was made between the Geodetic Survey of Canada and the city of Montreal, whereby the former was to supply the engineers to do the actual triangulation, and the city of Montreal was to furnish the materials for observation towers, and construct all the monuments and permanent marks of the survey.

Work was begun on April 12, when the writer went to Montreal, and after a consultation with the engineers of the Public Works Department of the city of Montreal, to find out what distribution of points would be most useful for the needs of the engineers in mapping, the reconnaissance for the triangulation was begun.

The general scheme of the triangulation was to have one strong main net, composed of stations on commanding points, and based on the line Royal-St. Hilaire, from which line the distances were stepped down to seven points lying either just outside or within the city. From these seven points which constituted the main net, control points were established all over the city and surrounding district, by intersections from three or four of the main stations. The directions which fixed the positions of the main stations, as well as the intersections on the control points, all being determined by a 12-inch direction theodolite, with the exception of a few angles from three stations.

The distribution of these points throughout the city and the manner in which they were determined from the main scheme is shown on the sketch on page 26.

In this respect the Montreal triangulation differs from that of most cities, such as New York or Paris. In the latter cases a great many more stations were occupied as instrument stations, many of them being on the tops of buildings. This plan gave an enormous number of lines with a correspondingly large number of condition equations, and a consequently heavy adjustment. The plan adopted for Montreal being much simpler was much more economical, while the direction method of observation from the towers of the main scheme, where the atmospheric conditions were good, gave a very high degree of accuracy (the average triangular closing error being only 1·2 seconds) which made a large number of conditions unnecessary in order to obtain the required precision in the location of the control points.

The towers had the advantage over stations on the tops of buildings as instrument stations, in that the air around the towers was not so much affected by heat waves, as that on the top of a building. Also field reductions were simpler due to the absence of eccentric stations, which generally have to be used when the station consists of a flagpole or similar object.

The stations in the main net were Royal, St. Hilaire, Brosseau, Tremblay Drummond, Dickson and Westmount. From this main net the stations Lachine and Ste. Dorothée were located, the latter one was occupied with the direction instrument and used as one of the main stations. From the main stations intersections were then made on the control points, each point being read on from three, and in some cases, four of the main stations, with the exception of a few in the southern portion of the city which were only visible from two. These were then read on by the repetition method either from Lachine, or from the city hall or Northern Electric, the latter two being already well determined from the main stations.

The control points which were established as above were all well-defined points such as the tops of church spires, bases of flagpoles, etc., on stone or brick buildings, and were all so selected that their positions could be easily and accurately transferred to permanent marks on the streets. In the parts of the city where no sidewalks were built, these marks consisted of copper bolts set in the top of concrete monuments, which projected about six inches above the surface of the ground. Where concrete sidewalks were present the marks consisted of copper bolts leaded into the concrete.

A transit can be set up over any of these marks, and good sights can be obtained in almost any direction, so that precise traverses between any two of them can be adjusted both for bearing and distance. They are so distributed that a survey in any part of the city or surrounding municipalities can be conveniently tied to some two of them. Thus a framework for mapping control of great accuracy is provided sufficient both for present and future needs.

The reconnaissance to determine the position and heights of the towers for the main scheme was carried out by means of the portable tower, described in the report of the Superintendent of the Geodetic Survey of Canada for 1919. It was very effective under the conditions found around Montreal, especially in the northern and eastern sections of the city where the ground was fairly level, with numerous high buildings. It was necessary for the lines of sight to pass clear of all these buildings; otherwise extremely high towers would have been necessary. At one station the portable tower was erected four times within a radius of one quarter mile before a definite point could be found which fulfilled the above conditions. It can readily be seen that it is almost indispensable for work of this nature.

In addition to the work for the city of Montreal the geographic positions of about seventy church spires and water tanks in various towns and villages, within a radius of forty miles from the city, were established by intersections from three triangulation stations, the McGill University longitude station and the triangulation of the Hydrographic Survey were also tied into the triangulation of the Geodetic Survey of Canada.

CONTINUATION OF THE ST. LAWRENCE RIVER TRIANGULATION

Lindsay O. Brown, Geodetic Engineer, reports as follows on the continuation of the St. Lawrence river triangulation for the season of 1919.

This was a double party with two engineers. The number of men in the party varied, but on an average there were ten lightkeepers in addition to recorders and cooks. As the other engineer occupied stations on the north side of the river where transportation was difficult, he had with him a camp helper also.

The whole party went into camp in May, and two weeks were spent in training lightkeepers. As the men were working under actual field conditions their progress was rapid, and at the end of the two weeks' training they were competent to take charge of their stations.

At the beginning of the season considerable difficulty was experienced on account of men leaving the work. The new members of the party were all soldiers, and they found life in camp alone or with one companion very irksome after years at the front. At the commencement of the season it was found necessary to build a small tower at St. Simeon. This work was done by the same method as described in last year's report. Four primary and four secondary stations were occupied by the writer, and from these points a large number of lighthouses and churches were observed. From the observations made this year by the two observers, in addition to what was done last year, the positions of some ten lighthouses between Murray Bay and Rimouski are fixed for the use of the Department of the Naval Service. The positions of the same number of villages were also fixed for the chief geographer. In addition to this half a dozen lighthouses and churches have been observed from two stations.

Under instructions received towards the end of the season, the writer proceeded with one assistant, to erect signals on various mountains in the interior of Gaspé. These mountains, after their positions have been determined, are to be used as range points for the Department of the Naval Service in their work of taking soundings. As the season was so advanced and as travelling had to be done by boat or on earth roads, the most easterly one of these signals was first located. This point is situated near the Madeleine river, about seven miles from the Great Eastern Paper Company's mill. The manager and the engineer of this company provided a canoe, lumber and boarding accommodation, and lent men from their mill to aid in the work. Acknowledgment is made of the indebtedness of the Geodetic Survey of Canada to the Public Works engineer for Gaspé, Mr. J. T. Bertrand, for useful information relating to the country. He intends to make application for the exact determination of the position of many of the prominent hills in the interior of Gaspé. This is with the intention of having maps made for the location of roads and railroads. These maps are necessary as the interior of Gaspé is practically unknown, and existing maps are incorrect, or at best, sketchy. The country is very heavily timbered with tall spruce, and minerals have been found in paying quantities, though the country has never been prospected thoroughly. The rivers are shallow and swift, so transportation must be by road or rail.

DIRECTION MEASUREMENT ON THE LOWER ST. LAWRENCE.

W. C. Murdie, in charge of a Direction Measurement party, on the Lower St. Lawrence river, submits the following report on the operations of his party for the field season of 1919.

The work of the field season of 1919 extended along the St. Lawrence river from Murray Bay eastward about 100 miles. As a result of the work, the triangulation net of control has been extended over an area of approximately 4,800 square miles.

The country on the north shore covered during the season is generally speaking, rough, rocky and sparsely settled. It is partially covered by a poor quality of spruce, jackpine, balsam, birch and poplar. Small patches of this district have been cultivated, but a very small percentage of the land is suitable for agriculture on account of its rocky nature. Most of the existing timber is suited only for pulpwood.

On the north shore from Murray Bay east to Portneuf, a distance of approximately 100 miles, there is a wagon road, but owing to the many bad hills travelling is difficult. No land route exists below Laval bay. From the end of the wagon route the only means of travelling is by boat on the St. Lawrence river. The harbours on the north shore are not the best and it is difficult to enter them except at high tides.

Direction measurements in this area were carried on by two observing parties which may be termed the north, and the south shore parties. The south shore party was in charge of Mr. L. O. Brown, Geodetic Engineer, while the north shore party was managed by the writer.

The season extended from May until the third of October. At the close of the season the equipment was stored at Trois Pistoles, P.Q.

The results obtained by the north shore party are as follows:—

Primary stations occupied	6

From these six stations directions were measured on the following objects in addition to those on primary stations:—

Lighthouses	22
Churches	38
Supplementary stations	4

As a result of this season's work, carried out by the two observing parties, sufficient information has been obtained to develop the geographic positions of eleven lighthouses and thirteen churches, while sufficient observations have been taken on three lighthouses and nine churches to give a reasonably accurate value of their positions.

The weather throughout the season was quite varied and there was a considerable amount of time unsuited for measurement due to rain, haze or smoke resulting from bush fires. For example, near the beginning of August there was a period of ten days when the south shore was entirely cut off by smoke and haze. Near the end of the season low temperatures so affected the instrument used that work was retarded. The ranges of temperature also required extra time to adjust micrometers which were constantly going out of adjustment.

The first section of the personnel of the two measurement parties left Ottawa on May 6 and proceeded to Trois Pistoles and set up a training camp for new recurits under an experienced man. On May 13 the second section, including the chiefs of the north and south shore parties, proceeded to Trois Pistoles. Approximately ten days were employed in training and preparing outfits. Then the various parties moved to their appointed stations.

On May 21, the north shore party proceeded to Murray Primary Geodetic station. On that date there was still considerable snow left on the mountains and this, together with water, and trails suffering from the effects of the past winter, made progress slow and difficult. Thus a considerable length of time was necessary to become established and ready to commence measurements.

No sooner had the work commenced than several of the lightkeepers of the two parties sent in their resignations, stating that they did not like the work. This had a crippling effect and caused considerable delay. Throughout the season communication between engineer and lightkeepers was not of the best either by letter or by telegram.

At the beginning of the season the north shore party was made up as follows: a measurement party comprising an engineer, recorder and cook, and three or four lightkeeping parties of varying strength, of one or two men depending on the difficulty of the stations occupied. The above establishment existed up to July 15, when additional personnel was added, including an assistant for the measurement party and a boat crew of four for the sixty-five foot launch.

The reasons for this increase were as follows:—

(*a*) On account of the amount of extra work including the preparing of stations, cutting or clearing trails and man-packing, an extra man was necessary to save time so as to enable the engineer to take advantage of all available clear weather.

(*b*) On account of transport problems, the launch had to be introduced not only to save time, but to give the only means of reaching many points which had to be visited.

TRIANGULATION SURVEY OF THE CITY OF HALIFAX

H. F. J. Lambart, Geodetic engineer, left Ottawa August 6, under instructions to make a triangulation survey of the city of Halifax; this was carried out and completed on September 20.

Control.—This survey is controlled entirely from the four points of the primary quadrilateral Dartmouth, Flandrum, Camperdown, Geizer, with one interior point Halifax.

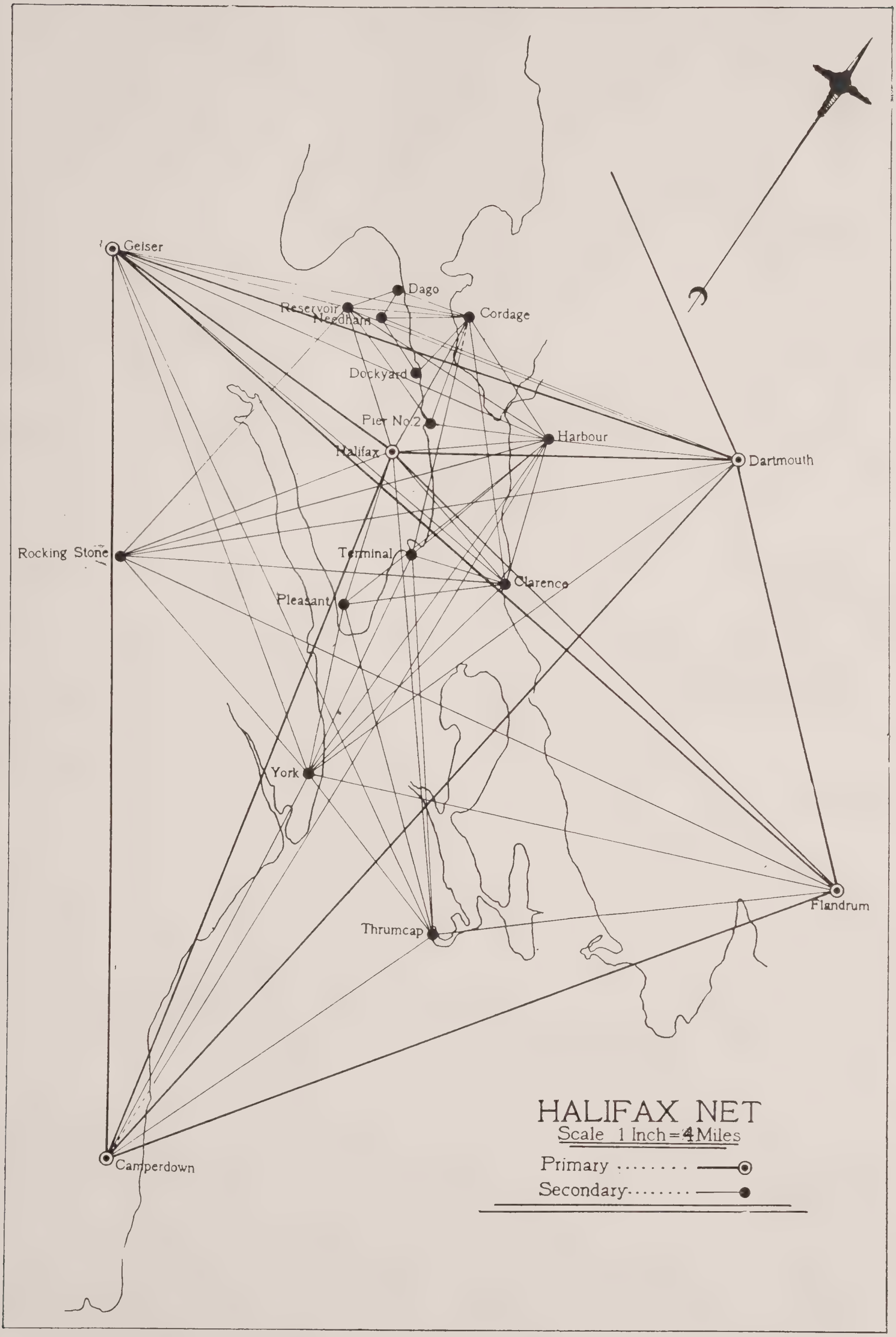
Connection with other Surveys.—This survey is connected to the Admiralty Survey at two points, York (hydrographic station, Position) and Little Thrumcap. These two Admiralty points are marked by hexagonal steel bars projecting above the surface about two and a half feet and securely leaded into the solid rock. Both these points were occupied. The Canadian Hydrographic Survey's triangulation shows a connection with the British Admiralty point, Position, while our connection with the Hydrographic Survey was made by intersections only, on Devil's Island E. Lt., Chebucto Head Lighthouse and Sambro Lighthouse.

Some time after the explosion of December, 1917, the astronomical pier at the north end of the harbour front was demolished and last year one of the reference points of the pier (Creighton Company's store) was also destroyed. In the summer of 1918, Mr. Louis B. Stewart tied in this old store corner to three manholes on Roome street and deduced the position of the astronomical pier from these three manholes.

A triangulation station Dago (Pt. 15 shown on accompanying sketch) was established nearby and the three manholes connected up with the triangulation survey by a measured base and the measured three angles of a triangle. (See field notes, Book II, pages 34-37, and Field Computations.)

Marking Station.—Twenty stations in all were occupied, which included the five primary points previously referred to. All, with the exception of three, and the four primary points Dartmouth, Camperdown, Flandrum and Geizer, were marked with the Geodetic Survey brass tablet set in a concrete pier, or set in the solid rock. Many of these were leaded where found necessary, as well as being fixed by the wedge at the end of the bolt.

The primary point Halifax, and the two secondary points Cordage and Harbour are situated on flat roofs, the latter on account of its lack of permanency has been connected to the ground point Maynard by measured base and three angles of a triangle.


Geiser
Dago
Reservoir
Needham
Cordage
Dockyard
Pier No.2
Harbour
Halifax
Dartmouth
Rocking Stone
Terminal
Clarence
Pleasant
York
Thrumcap
Flandrum
Camperdown
HALIFAX NET
Scale 1 Inch = 4 Miles
Primary
Secondary

Signals.—Over all points, except where the three towers exist, i.e., at Geizer, Flandrum and Dartmouth a standard signal has been erected, consisting of a 21-foot centre pole tapered and cut away 6 feet from the ground, with two 30-inch targets one below the other, set at right angles with white centre and 6-inch black border.

Material in Signal.

1—2 inches x 3 inches x 14 feet, tapered 9′ of its length to ½″ at top.
6—2 inches x 3 inches x 14 feet, tripod legs and horizontal side braces.
7—1 inch x 3 inches x 14 feet, diagonal sway braces and horizontal upper tier.
1—1½ inches x 1 inch x 10 inches, for cross-arms of targets.

This material was made up into a single bundle and delivered to any part of the city by the Piercy Supply Co. for $5.

Area Covered.—The area covered by the complete net includes the city of Halifax, harbour and southern part of the Bedford basin, as well as the entrance to the harbour as far out as a line drawn from Devil's Island to Chebucto Lighthouse.

Triangle Closures.—All horizontal angle measurements were made with the 6¼ inch Berger reading to 10 seconds, as described in the 1918 report of the St. John-St. Andrews net. Twelve repetitions were taken on triangulation points and six on points that were cut in i.e., lighthouses, church spires, etc.

About one hundred triangles were closed in the scheme. The average closure was 4 seconds, but the correction to each angle, due to failure of horizon closure at each station, is not much greater than half a second. This rather large triangle closure can, therefore, only be explained by a warping and lack of centering of the signals over the points. This has affected materially the closures on a number of short sights right in the city. The signals were centered when built, but some time elapsed before the observing commenced and during this period many had warped slightly and others had been disturbed by the inquisitive young public.

The net covers about 125 square miles of country, embracing the city of Halifax, Halifax harbour and outer entrance to same. (See sketch p. 45)

GEODETIC POSITIONS AS CONTROL FOR THE FRASER RIVER RECLAMATION SURVEY

H. B. Kihl, Geodetic Engineer, reports as follows on work done by his party in British Columbia during the past season.

On May 28, with J. H. Kihl as assistant, the writer left Ottawa for Vancouver and there engaged three returned soldiers as helpers. For the purpose of transportation a motor-car was purchased from the Ford Motor Company.

OBJECT OF WORK.

The object of the work was to establish a number of geodetic positions as control for the Fraser River Reclamation Survey.

RECONNAISSANCE.

Reconnaissance was commenced June 5. Starting from four previously established geodetic stations, namely, West Base, Little Mountain, Grouse and Atkinson as bases, the triangulation was carried south to English Bluff on Pt. Roberts and east to Pitt Meadows. Seventeen triangulation stations were located, six along the east coast of the strait of Georgia from Pt. Grey to English

Bluff, serving as bases for the hydrographic survey of the Department of the Naval Service, and eleven stations from Vancouver eastward as control for topographic work. The most easterly station was located near the junction of Pitt river and the Lillooet river.

PREPARING STATIONS.

The preparation of stations consisted of building towers and target signals, and cutting out lines. Whenever possible the station was prepared at the time of location, thus saving the time of an extra trip to the station. This was done on most of the stations where signals were built, only two or three hours being needed to erect a target signal. It required from one to two days to build each observing tower, according to size. Five towers, ranging from twenty to forty feet in height were built and target signals were erected on thirteen stations. Lines were cut on Burnaby, Westminster, Mann and English Bluff.

MARKING STATIONS.

Nine stations were marked by copper bolts placed in concrete piers sunk about four feet in the ground and projecting one foot above the surface of the ground. Seven stations were marked by copper bolts sunk in rock and one by a wooden post with reference marks.

OBSERVING.

The horizontal angles were observed with a 5-inch Troughton and Simms 2-micrometer transit. Four direct and reverse positions were read on each direction. Owing to bush fires and local smoke, signals for the greater part of the season could not be seen and lamps had to be used. This necessitated frequent moving of the lightkeepers. Often one or two lightkeepers were moved from one station to another on the same night. The motor car was a great help in rapid transportation and enabled us to take full advantage of any good weather.

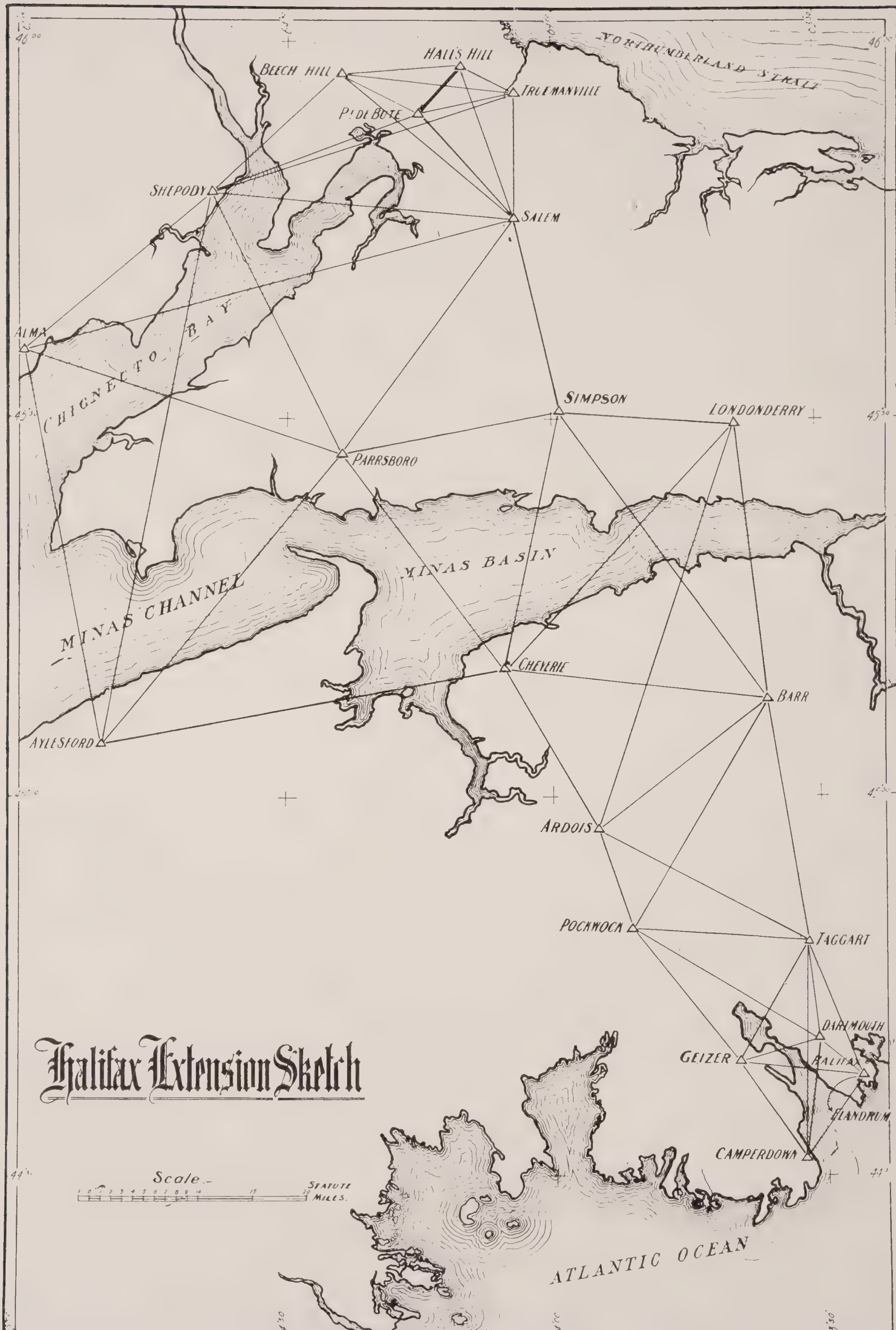
In all seventeen stations were occupied with the instrument and seven points established by intersections.

PRIMARY TRIANGULATION WORK IN NEW BRUNSWICK AND NOVA SCOTIA

J. E. Ratz, Geodetic Engineer, submits the following report on primary triangulation work in New Brunswick and Nova Scotia.

The object of the season's work was to complete the connection of the Westmorland base net with the Bay of Fundy triangulation; to extend the latter eastward along Cobequid bay; to carry a subsidiary scheme southward to the coast at Halifax, thereby furnishing control points for the Hydrographic and other coast surveys, and to control the Halifax Harbour survey being made by the Geodetic Survey during the same season. (See sketch on page 48)

As the above required that fifteen primary stations be occupied, a double observing party with eight lightkeepers was used, the observing being done by C. H. Brabazon and the writer. Each lightkeeper was equipped with two lamps, these being shown from the lampstand and from the tripod whenever both observers were reading on the same station. Previous to commencing observing on May 7, the men, mostly returned overseas signallers, had been thoroughly instructed at a central camp in the use of code and details regarding their duties. This method gave assurance that the ordinary difficulties usually met with by the lightkeeper could be handled and correctly overcome, while the



NORTHUMBERLAND STRAIT
BEECH HILL
HALL'S HILL
TRUEMANVILLE
Pt. DE BUTE
SHEPODY
SALEM
ALMA
CHIGNECTO BAY
SIMPSON
LONDONDERRY
PARRSBORO
MINAS BASIN
MINAS CHANNEL
CHEVERIE
BARR
AYLESFORD
ARDOIS
POCKWOCK
TAGGART
DARTMOUTH
GEIZER
HALIFAX
GLANDRUM
CAMPERDOWN
Halifax Extension Sketch
Scale.
STATUTE MILES.
ATLANTIC OCEAN

fact that they were efficient signallers from army experience insured speed and accuracy in transmitting messages. In all seven primary and two supplementary stations were initially occupied; four others were reoccupied. These supplementary stations are within a mile of the shore as it was felt that they would be of greater assistance and would involve less work to other surveys than our primary stations further removed.

Observing was commenced at Salem and on May 17 the party moved to Parrsboro. The station is situated some three miles from the shore at a part of the bay where the rise and fall of the tide is at a maximum, nearly fifty feet. The results of lines across the bay were accepted with some diffidence on account of the possibility of the tides causing unusual displacements of the lines of sight. The lines on the north or shore side closed the triangles satisfactorily, but no immediate check other than agreement of readings on several nights was available for those across the bay. Later the station was reoccupied to check these lines under different conditions. The new readings with reference to the initial gave changes of $+ 2''$ and $+ 1{\cdot}5''$. It is thus seen that the angle between the lines was held fairly constant. The data are all too slender to warrant any conclusions being drawn as to the effect of the tides on horizontal measurements, as the number of lines is insufficient and the actual observed difference in this case is well within that which has occurred on lines passing entirely over land and well inland. A study of this effect should include such facts as strength and direction of wind, time of tides, directions of flow of tide, height of line above water, etc. The entire Bay of Fundy triangulation might, or might not, furnish some definite relation between tides and excessive closures of triangles, but the experience during the summer has been that the tide does not cause any very excessive changes in the line of sight.

One of the main difficulties at this point was the poor visibility of Greer, fifty miles away, on the north shore. There was no doubt as to the line being open as the hill could be seen before sundown. However, with sundown rolling banks of mist and fog over Chignecto bay would completely shut out the view. In five weeks' stay the light was visible on two nights only and then so faint that readings could be made just so long as there was sufficient sky reflection to illuminate the cross hairs.

By the middle of August sufficient progress had been made to ensure that a connection would be made at Halifax, so a reduced party proceeded to the Westmorland base net to effect better closures in a few of the triangles. The average closure of the twenty-one triangles involved in the net was reduced to $0{\cdot}7''$. From here the party proceeded to Parrsboro to reobserve the lines mentioned above.

On September 13 the party proceeded to Moose island where a tower 55 feet high was erected by three men in ten days. Improvised equipment was generously furnished by the Cumberland Coal and Railway Co. at Parrsboro.

The party then proceeded to Halifax district and assisted in the completion of the work.

The use of a one-ton Ford truck greatly facilitated travelling and transportation. The engine gave good service in most cases, but in hilly districts is much too light for the load carried.

PROGRESS IN RECONNAISSANCE ON THE LOWER ST. LAWRENCE.

Professor Louis B. Stewart submits the following report of reconnaissance on the lower St. Lawrence made during the summer of 1919.

The writer left Ottawa on June 5 for Quebec to look for a suitable launch to rent for the season's work, and was joined there by Mr. Rannie on the 7th.

The search in Quebec having failed, the writer, accompanied by Mr. Rose, who had come to Quebec on the same day, set out for Rimouski, where, on the 10th, a boat that might answer was located. This launch belonging to Dr. L. F. Lepage looked fairly satisfactory, and not wishing to spend more time in what might be a fruitless search it was decided to rent it. As the owner was out of town the time was utilized until his return in going to Mont Joli and Sandy Bay and preparing the stations at those places selected by Mr. Rose before coming to Quebec.

Having rented the launch, some days had to be spent in painting it, engaging an engineer, and having the engines put in running order. By the 21st everything was ready, and on the morning of that day, taking advantage of high tide, the party left Rimouski and ran across to Mille Vaches. The following morning the station—Iberville—previously established within two or three miles of the village, was visited; and from what was seen from there it was decided that the next station easterly on the north shore might be located on a hill beyond Laval bay.

Before leaving Mille Vaches a pilot was engaged who knew the coast as far as Godbout, as experience at Mille Vaches bay had shown that a serious risk is incurred in entering unknown harbours on this shore without a local knowledge of the channels.

The launch proceeded then to Laval bay, and anchored just inside the mouth of the river of the same name. The summit of the hill sighted from Iberville station was soon found, about two miles north-easterly from the mouth of the river, and there the next station, Laval, was located.

As the land near the mouth of the Bersimis river is comparatively low, it was decided that a tower would be necessary if the next station were placed there. An attempt was made to avoid a tower by triangulating the positions and heights of a number of hills situated ten or twelve miles inland from the St. Lawrence, measuring a base line on the sand at the mouth of the Bersimis. We then ascended that river. Several of the hills lying near the banks of this river, were examined, but none suitable for a station were found, the highest being in an almost inaccessible region several miles back from the river. The station was therefore placed near the shore and towards Pt. Michel. A 50-foot tower was there built between July 14 and 21, with the help of two hired men, and ropes and tackle borrowed in the villages at the mouth of the river. The time spent in building the tower provided an opportunity for repairing the bow of the launch, which had been damaged by striking a rock while ascending the Bersimis river.

A fact worth noticing, which was brought out in the course of the work, was the abnormally large value of the coefficient of refraction often observable on lines crossing the river. Thus, to an observer standing on the beach at Bersimis the light at Father Point was always visible, and that at Metis two nights in three, whenever the air was sufficiently clear. A calculation based upon these facts gives a value about 0·32 for the coefficient of refraction. Later observations, however, made on the south shore of the river, showed that this value cannot be depended upon by the reconnaissance in deciding upon the necessary heights of stations.

It was proposed to place the next station just east of the Manicouagan river, but, finding nothing there of sufficient height to give a sight line clear of Manicouagan point, the party proceeded to establish a station at St. Nicholas, being misled by the height, 700 feet, assigned to it by the charts. Finding, however, that its height is only about 400 feet, it became necessary to put an intermediate station on Manicouagan point, where a 50-foot tower will probably be required, as the land is thickly wooded. This arrangement of the stations was afterwards found to combine better with the points selected on the south shore, to give a good triangulation scheme, than that first proposed.

A careful examination was then made of the country in the vicinity of Pointe des Monts, between Godbout and Trinity bay, with the result that a station was located on a ridge immediately to the east of St. Augustine cove, and another about four miles northerly from Trinity bay. These stations have not yet been prepared. From the latter a clear view should be obtained of Cawi island, and possibly of Seven Islands.

On August 31 the party returned to Godbout en route to the south shore, and there met Mr. Rannie who had arrived the day before on the Alcestis. Crossing over with him to Matane, after sending the launch back to Rimouski in charge of the engineer, a guide was secured through the assistance of Mr. E. S. Holloway, chief engineer of the C. and G. T. Railway and the party set out on September 3 for a mountain among the Shickshocks in Leclerc township that had been sighted from several points on the north shore, and which appeared to be a good location for a station to be used in extending the triangulation down the Matapedia valley. The summit was reached towards the end of the second day, after a journey of thirty-five miles by wagon from Matane to one of Price Bros. lumber camps—the last twenty-two being over very rough bush roads—and a walk of eight miles through the woods. The height of the mountain is about 3,600 feet above the sea, and it will be a good site for a station as it commands an extensive view in all directions, and to the south for a distance of over forty miles. Another prominent mountain about fifty miles southeasterly from Leclerc, which was not visited, but which was observed from the north shore, will serve for another station. There is a road leading from Sayabec to its summit, on which there is a fire-ranger's observing tower.

Stations were then established about two miles south-westerly from Matane, at Cap des Mechins, and at Cap Chat. These were all prepared for occupation.

Observations for magnetic declination were taken when opportunity occurred.

The reconnaissance was continued easterly by Mr. Rose to Mount Edward, which had been sighted from Cap Chat and also from Mechins. The site for a station there was selected.

A sketch showing the reconnaissance accomplished during the season of 1919 is shown on page 28.

MEASUREMENT OF HORIZONTAL DIRECTIONS IN THE MARITIME PROVINCES CONTINUED.

Claude H. Brabazon, Geodetic Engineer, reports as follows: In accordance with instructions, the writer left Ottawa April 22, 1919, to continue the measurement of horizontal directions in the Maritime Provinces.

TRAINING LIGHTKEEPERS

Camp was made at Point de Bute, N.B., on the 24th with one man and a cook, it having been previously arranged that the lightkeepers for two parties should be assembled at this point and be given a course of training in the duties required for their special work.

On April 25, eight additional lightkeepers arrived and were at once taken in hand for instruction in the use of the compass, telescope, signal lamp, signal code, etc. The camp was within a mile of the "tower" which stands over the primary geodetic station at the eastern end of the Westmorland base line, and was thus an ideal location for a training ground. The time spent in this preliminary instruction, about ten days, was well repaid, as every man on the party performed his duties without a hitch throughout the season and, as a consequence, vexatious and costly delays met with in former years through lightkeepers being unfamiliar with their work were avoided.

BAY OF FUNDY REGION

Mr. J. E. Ratz, Geodetic Engineer, with whom the writer was to co-operate in carrying on the survey, arrived May 2. Two parties were then organized and, the lightkeepers with complete outfits having been placed at their respective stations, camp was broken on the 7th, Mr. Ratz going to Salem, while the party in charge of the writer went on to Truemanville, N.S., where operations were commenced by occupying the primary geodetic station of that name. From Truemanville the party moved to the south shore of the bay of Fundy, occupying Aylesford, Cheverie and Barr, thus carrying the measurements in the Bay of Fundy net to the head of Cobequid bay. From the primary stations and from supplementary points which had been located along the shore, measurements were taken on lighthouses, church steeples, domes of buildings and water tanks, which were thus established as control points for the Hydrographic and other surveys.

HALIFAX NET

A primary net based on the line Cheverie–Barr was extended southward to the coast at the entrance to Halifax harbour. From stations in the last quadrilateral of this net, lighthouses along the coast and in the harbour, as well as a point on the Citadel at Halifax, were sighted on and established as control points for the Hydrographic survey, Militia surveys, Halifax Harbour and other surveys.

GENERAL REMARKS

This brought the operations, covering an approximate area of 6,000 square miles, to a close for the season. Much better progress was made in the field in 1919 than heretofore, owing chiefly to the improved weather conditions, which were the best experienced in the eastern provinces since 1914. Also the 1-ton motor truck supplied by the department was of the greatest service in getting the engineers and lightkeepers quickly and economically from place to place.

CLOSE OF SURVEY

The party was disbanded at Dartmouth, N.S., and the instruments shipped to Ottawa October 27.

To be convenient to the geodetic stations Nutby and Camden, where the operations of 1920 are to commence, the camp outfit and motor truck were stored with a farmer near Truro. The writer left next day for Ottawa, arriving here October, 31 1919.

SUMMARY OF OPERATIONS

The following summary shows the work accomplished during the season of 1919:—

Primary stations occupied	8
Primary stations re-occupied	2
Primary stations read on	51
Supplementary stations occupied	3
Supplementary points sighted on	10
Lighthouses sighted on	25
Church spires sighted on	22
Horizontal angles measured	96
Vertical angles measured	96
Traverse angles measured	44
Reference bolts placed	10
Cement pier for marking station, 3′ x 3′ x 18″	1
Traverse lines chained	3·5 miles.
Vista opened 20 feet wide	2 "

Site of Triangulation Station "Mechins" on the South Shore of Gulf of St. Lawrence in Matane County, Queaec.

Site Point near Triangulation Station "Mabou" on Cape Breton Island showing the Rugged Character of the country.

RECONNAISSANCE IN NOVA SCOTIA AND PRINCE EDWARD ISLAND

Hazen P. Moulton, Geodetic Engineer, submits the following report, on reconnaissance in Nova Scotia and Prince Edward Island, during the past season.

On April 27, with Mr. W. N. McGrath as assistant, the writer left Ottawa and proceeded to the Maritime Provinces. The object of the season's work was to extend the primary triangulation, and to locate such secondary stations as might be required to furnish control for other surveys along the coast.

Truro, N.S., being centrally located with reference to the summer's work, was selected as local headquarters for the greater part of the season. Here the writer states that the post office Officials of that town were very kind and courteous, and by their prompt care in forwarding mail to various parts of the province, rendered most excellent sevice, both to his party and to the members of the building and direction measurement parties.

During the month of May, secondary triangulation stations were located at Advocate, Moose Island and Selma, close to the shores of Minas basin and Cobequid bay. These three were ground stations and were marked by the usual copper bolts set in rock. Lamp stands were erected and a few trees were cut, opening lines to the primary stations. A secondary station was also located at Penny's Mountain, near Truro, and this station was given permanency by the erection of a concrete base.

The months of June and July were spent on a revision of the Halifax net. All of the stations selected by Professor Stewart in 1918 were visited, and some of the lines were tested with lights. As a result of the investigations it was found necessary to introduce a new station, requiring a 45-foot tower, near Pockwock lake; and also the position of station Taggart was changed to a higher and wooded hill about a mile southwest from the former point. On this new point a lamp stand was erected and two lines were opened through light bush. The remainder of the lines were left for the lightkeepers to clear.

In Halifax county, primary stations were selected at Dartmouth, Flandrum and Camperdown. These stations were required to furnish control for a survey of Halifax harbour, and also to establish the positions of several lighthouses along the coast.

The remainder of the season, till November, was spent in extending primary triangulation, both east and north, from the line Nutby—Camden. Eight primary stations were located between Pugwash and Antigonish, and two in Prince Edward Island, on lots 60 and 46, thus forming a net covering the southern part of Northumberland strait. These stations will all require towers ranging about 45 feet in height.

In Pictou county, secondary stations were selected at Trenton and Greenhill. These points do not require towers, and the line Trenton–Greenhill will form a good base for a secondary triangulation net, which may be required in that county.

After selecting the various stations, the owners of the land were interviewed, and permission was obtained for the preparation and occupation of the stations. Descriptions were then prepared and sent to the parties requiring them.

Transportation during the season was effected by means of a Ford runabout with an express body, which gave good satisfaction, and resulted in a great saving of time.

RECONNAISSANCE IN NEW BRUNSWICK AND PRINCE EDWARD ISLAND

J. W. Menzies, Geodetic Engineer, submits the following report on Reconnaissance in New Brunswick and Prince Edward Island.

The reconnaissance carried on in New Brunswick and Prince Edward Island during the latter part of the season of 1919 had for its object the initiation of a scheme of triangulation that would extend northward along the east coast of New Brunswick and eventually connect up with the triangulation scheme running eastward along the valley of the St. Lawrence river.

A central point figure composed of the stations Shepody, Salem, Sackville, Welch, Botsford and Indian was used in order to get started from the line Shepody to Salem which was considered the best line in that locality.

Proceeding north two stations were located in Prince Edward Island (Egmont and West Point). On the mainland another station St. Jean was located near Buctouche, N.B., the site of which may be changed when a further reconnaissance is made; however owing to the necessity of keeping the line to Botsford open, it cannot be shifted very far.

It is hoped that a point can be found somewhere to the east of St. Jean which would connect up with Indian and another point to be located somewhere between Richibucto and Richibucto Head. This last point would be connected with West Point station and St. Jean used as a central point. From this figure a satisfactory side would be obtained for extending north.

TOWER BUILDING

In the absence of N. E. Kelly, Senior Construction Foreman, the following report on tower building operations in Quebec and Nova Scotia during the season of 1919, is given by J. L. Rannie, Supervisor of Triangulation:

The work of the party consisted as usual of building observing towers or instrument stands for the primary triangulation engineer, the marking and referencing of stations, together with the building of signals, etc., for secondary triangulation.

The party commenced work in the spring building towers for the Montreal vicinity triangulation and moved about the end of June to Nova Scotia to build the required towers ahead of the direction measurement parties for the net from Truro to Halifax.

The same organization was used as in the previous year consisting of one carpenter construction foreman, one construction foreman, three carpenters and one cook.

For moving camp the party had its own motor truck, which gave excellent satisfaction. It is of interest that this truck was used wherever possible to raise the towers into position. For this work a truck is much steadier and more reliable than horses.

Five towers were erected in the Montreal district as follows:

1 with 70-foot tripod, 76-foot scaffold.
2 with 60-foot tripod, 66-foot scaffold.
2 with 45-foot tripod, 51-foot scaffold.

after which the following number were built in Nova Scotia.

1 with 70-foot tripod, 76-foot scaffold.
4 with 60-foot tripod, 66-foot scaffold.
1 with 50-foot tripod, 56-foot scaffold.
2 with 45-foot tripod, 51-foot scaffold.
1 with 20-foot tripod, 26-foot scaffold.

The sketch on page 57 shows a plan of a typical observation tower, the height of the inner tripod on which the instrument is set being 60 feet, 6 inches. The surrounding four-legged scaffold is 66 feet high and is surmounted by a light-keeper's table for posting a lamp to show to the engineer occupying another tower.

Eight concrete monuments were placed to mark triangulation stations in bush where the stations would otherwise have been difficult of recovery (see page 38 for illustration), while three stations were marked and referenced by copper bolts leaded into the rock.

K. H. ROBB, JUNIOR GEODETIC ENGINEER, REPORTS AS FOLLOWS:

The first part of the season of 1919 was occupied in clearing and preparing triangulation stations, in the vicinity of the northeast coast of Vancouver island. This was completed on July 13 and work was commenced on the Fort Rupert base line on July 15.

PREPARATION AND CLEARING OF TRIANGULATION STATIONS

From May 1, with a party of four men, lines were cleared on the stations: Bullock, Elizabeth, Harbledon, Palmerston, Franklin, Klucksiwi, Numas, False Head, Dillon and Rupert.

The hills in most cases in the vicinity are heavily wooded with cedar, spruce and hemlock.

The line Dillon to False Head crossed two islands; the first about a mile from the Dillon end required a cutting half a mile long and the second, about two miles distant, required a quarter mile cutting to provide a vista thirty feet wide. At the False Head end a half mile of heavy timber was cut. Owing to the fallen timber and salal, travelling was difficult and considerable clearing was necessary in order to make room for the felling of the larger trees.

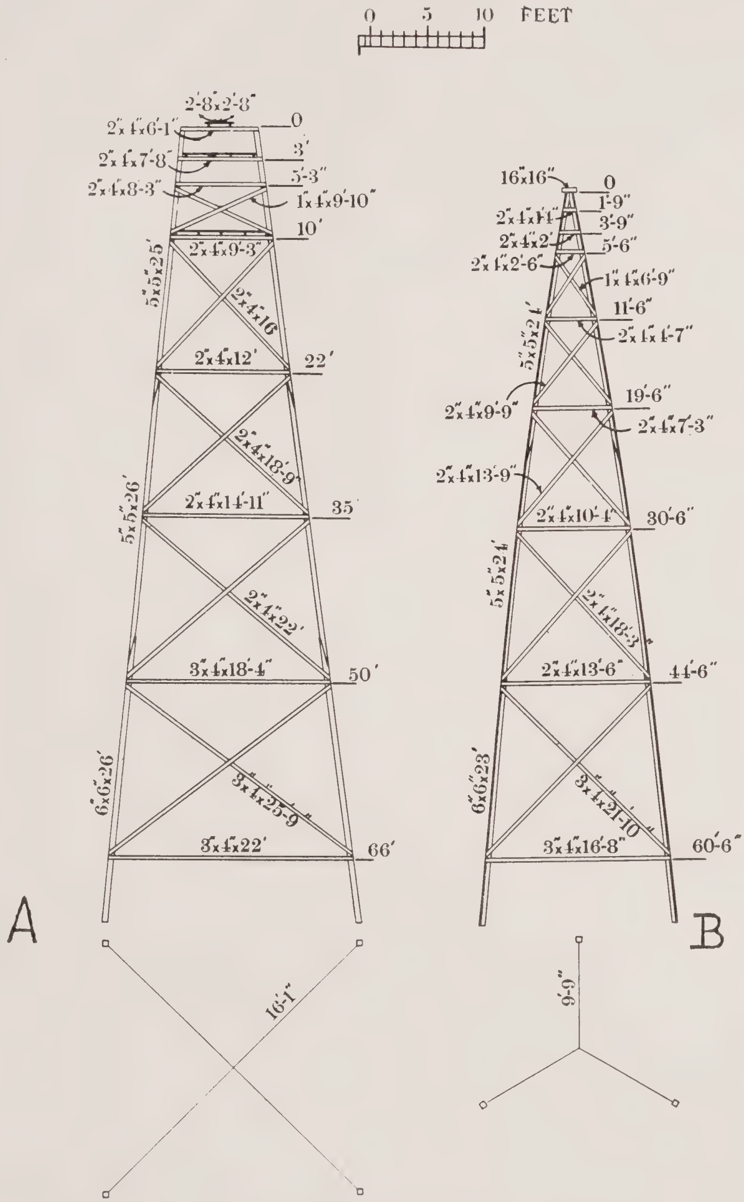
FORT RUPERT BASE LINE

The Fort Rupert base line was located in the summer of 1918. It is near the Indian village of Fort Rupert on the northeast coast of Vancouver island. The base line is about 5·9 miles long, has the west end on a small rocky knoll about one-quarter of a mile south of Fort Rupert, and the east end on a flat topped hill one-third of a mile south of False Head. The west end of the base is marked by a copper bolt leaded into the rock at a point about eight or ten feet south of the summit of the hill. This point was chosen in order to reduce the grade at this end of the base line.

The False Head or east end of the base is marked by a similar bolt placed in a block of concrete. Small towers of about seventeen feet in height were erected over the ends of the base for the purpose of observing the lines of the triangles. At False Head the continuous action of the wind and storm had blown the timber down and it was piled criss-cross to a depth of twelve or fifteen feet.

The whole line from Fort Rupert to False Head was covered by heavy timber with a thick growth of salal and small trees. The preparation of the line for posting and measuring took a good deal of time. The work of clearing commenced on August 1, 1918, from Fort Rupert end of the base, and by October 7 when work was discontinued for the season, the signal at False Head was visible from Fort Rupert. Owing to the demands of the army and to the

SIXTY FOOT TOWER



A: Elevation of side of Scaffold, and Ground Contacts.
B: Elevation of side of Tripod, and Ground Contacts.
The Centres of Scaffold and Tripod are in the Vertical of the Station.

scarcity of labour generally, experienced axemen were hard to obtain. Most of the men of the party were inexperienced in timber operations, some of them were returned soldiers just recuperating from serious wounds, yet in an interval of a little over two months the whole line from Fort Rupert to False Head was cleared out, many trees of diameter greater than ten feet had been cut, and immense quantities of undergrowth had been removed. In falling some of the trees considerable quantities of 40 per cent powder were used.

The work of preparing the line for measuring was commenced on July 15, 1919, with a party of four men. These were later augmented by five others, and the line was cleared, posted and ready for measurement by August 28. The timber cut in 1918, which had fallen across the line, had to be removed, as well as all old logs which had been rotting for probably the last hundred years. These old logs were generally covered with four or five inches of moss and bedded in the mud.

In order to remove all this debris of logs stumps moss and roots large quantities of powder were used. The progress at times was slow, but as water will eventually wear away a stone, so steady plodding and perseverence eventually succeeded in putting the base line in shape for measuring.

The posting of the line was carried along with the clearing, cedar posts were split as needed. At each fifty-metre point, commencing at Fort Rupert end, a four by four-inch post was driven into the ground with the centre of its top nearly on the line Fort Rupert to False Head. Intermediate posts two by four inches were driven in at the intermediate points or twenty-five metres from the fifty-metre posts. The positions of the posts were determined by means of a twenty-five metre steel chain, stretched with a tension of sixteen pounds on a spring balance. The tops of the posts were so cut as to make measuring convenient.

A tack on top of the posts was a guide to the engineer in placing the tape in position. In some places at the crossings of ravines or creeks it was necessary to use extra long posts, the longest being about eighteen feet, and to enable the tape to be placed at the top of such posts, scaffolds were built. On the whole base line there were probably twenty places where scaffolding was necessary on both sides of the posts. At four different points along the base line it was not possible to use the full fifty-metre length. Here a twenty-five metre distance was introduced, and a large post was placed at the edge of the creek. The next fifty-metre length was either carried over the ravine or the next fifty-metre post was placed at a suitable location. The half lengths of twenty-five metres were measured by reversing the tape and using either half.

The three fifty-metre invar tapes Nos. 3139, 3140, and 3141 were used in measuring the base line, Nos. 3139, and 3140 being employed on the first kilometre, Nos. 3140 and 3141 on the second, Nos. 3141 and 3139 on the third, and so on in rotation over the whole base. The programme followed was to use one tape, say No. 3139, from post 0 to post 20, forward in each kilometre. Then from 20 to 0 backward. Tape No. 3140 was then used in the same order. This gives four measures of each kilometre; two forward and two backward. The mean of each pair of backward and forward readings constitutes one determination of the kilometre.

Copper strips two inches long, one-half inch wide and one-sixteenth inch thick, nailed at the proper place on top of the post, served the purpose of carrying the lengths of the tapes along the base. Sometimes it was necessary to use two plates on a post, where the length to the next post would carry beyond or to the outside edge. In these cases set up's or set back's were read with a small steel scale. The recorder noted all set up's and set back's, temperature readings, time, weather conditions, and other information. A line of precise levels run over the tops of the plates on the posts gave elevations. The levels were tied to the mean sea-level at the mouth of the Kehoe river.

The measuring party consisting of nine men, was made up of two observers, one recorder, two weight-men, three tape carriers and one axeman. The tape was never allowed to touch the ground, and was carefully handled.

On account of the nature of the surrounding district no difficulty was experienced from wind. The whole length of the line is through a dense forest and a severe storm outside produced no effect along the base line.

The measuring of the base commenced on August 28 and was completed on September 8. Only one kilometre was remeasured and this was due to a post in a swamp changing its position. The difference between the lengths of any kilometre as determined by the two tapes in only two cases exceeded one millimetre and in these two cases it was only 1·8 mm. and 3·5 mm.

PRECISE LEVELLING IN 1919[1]

F. B. Reid, Supervisor of Levelling, submits the following progress report upon precise levelling operations during the season of 1919.

Five parties were in the field, in charge of Messrs. McMillan, Smith, Rainboth, Dalton and Sinclair.

1. Levelling by D. McMillan

This party left Ottawa on April 22 for Colonsay, Sask., and commenced levelling on the 28th, continuing the line from Yorkton which had been carried as far west as Colonsay the previous fall. The line was closed about four weeks later on bench-mark 33-D, of the Regina-Prince Albert line, at Saskatoon. A new line of levels was then commenced at the junction of the Canadian Pacific and Grand Trunk Pacific railways, 4½ miles east of Colonsay, and carried northerly along the latter road to Prince Albert, again closing on the Regina-Prince Albert line and completing a circuit through Saskatoon, Prince Albert and Colonsay. The closure of this circuit is 0·263 foot.

The levelling at Prince Albert being completed on July 28, the party moved back to the Saskatoon district and spent the balance of the season—till October 29—in rerunning the portion of the Regina-Prince Albert line between Warman and Regina. This line was originally run in 1912, being the first line of precise levels in that district; the completion of the large circuit Saskatoon-Tofield-Calgary-Lethbridge-Regina-Saskatoon in 1915 with a closing error of 1·28 feet indicated that there might be a large error somewhere, but it was not until the completion of the Yorkton-Saskatoon line mentioned above that the trouble was sufficiently localized to warrant rerunning any of the lines, having regard to the very large perimeter of the first circuit—over 1,200 miles.

The instructions issued for the rerunning called for the levelling to be done by precise methods, the same as the original. Provided, however, that if the first rerunning of a section agreed with the 1912 levelling within 0·010 foot $\sqrt{M}$ (M being the distance in miles between bench marks) the second rerunning might be omitted.

The instructions contained the further provision that the single-levelling (i.e., that run in one direction only) should be kept balanced as to direction; in other words the amount of north to south levelling should approximately equal the amount of south to north levelling, the idea being to compensate for the divergence which usually occurs between a single running in one direction and the mean of two runnings (forward and backward).

That this had the desired effect is evidenced by the fact that the net result of the new running between Regina and a point sixty-one miles north thereof (all single levelling but two sections) was exactly the same as in 1912.

[1]A map showing all lines run to date is attached at page 74.

Of the thirty sections between Regina and Warman twenty-one were double-levelled and nine single-levelled. In one section (near Dundurn) an error of about 0·45 foot was found in the original work, all elevations north of this point being raised thereby. The large amount of double-levelling along the northerly portion of the line was caused by discrepancies larger than allowable occurring in certain sections and cancelling out again in the next adjoining section; this may be taken as evidence that the intermediate bench mark has changed in elevation since its establishment in 1912. It seems that several of the bench marks have settled by amounts up to one tenth of a foot, these being mostly in cheaply constructed buildings on light foundations—such as are usually found in prairie villages. The concrete bench mark piers appear to have held their elevations perfectly.

During the progress of the rerunning fifteen additional piers of the standard pattern were built at selected points between Saskatoon and Regina and two other new bench marks were established, one of these replacing an old one which had been destroyed.

The rerunning above outlined included 49 miles of single-levelling and 141 miles of double-levelling, equivalent to a total of 165½ miles of double-levelling.

2. Levelling by N. H. Smith.

The work of this party was of a special nature and consisted in running a number of short lines in the vicinity of Vancouver. A full description of the summer's operations, accompanied by a sketch, will be found on page 9.

3. Levelling by A. J. Rainboth.

This party left Ottawa on April 22 for Irricana, Alta., and commenced levelling on the 30th. All the season's work was along the tracks of the Canadian Pacific railway, the first line being from Irricana to Medicine Hat via Bassano and the second from Bassano towards Empress and Swift Current. At the time levelling was discontinued on September 30, a point had been reached about 17 miles west of Empress, Alta.

A severe blizzard which occurred the first week in May blocked the railroads and caused considerable delay and inconvenience to the party. Wind and dust storms were a frequent occurrence during the earlier part of the season, as is usual in that section of Alberta. These of course were very detrimental to the levelling.

4. Levelling by G. F. Dalton.

This party left Ottawa on June 16 for Burketon, Ont., and commenced levelling on the 19th. The Canadian Pacific railway was followed from Burketon to Lindsay and thence northwesterly through Orillia to Port McNicoll; from the G.T.R.-C.P.R. crossing near Port McNicoll a branch was run along the Grand Trunk to the town of Midland and several permanent bench marks established in the vicinity. At Lindsay, Orillia and Midland connections were made with bench marks of the Public Works Department.

On the completion of the above work on August 21, the party moved back to the neighbourhood of Lindsay and ran northerly from there along the Grand Trunk railway to its junction with the Canadian National railway at Howland and thence along the latter till the close of the season's operations on October 3, when a point had been reached 26 miles east of Howland.

5. Levelling by G. E. B. Sinclair.

This party left Ottawa on May 6 for Three Rivers, Que., and commenced levelling on the 8th, continuing the line from Montreal which had been carried as far as Three Rivers in 1917. The Canadian Pacific railway was followed to

the crossing of the Canadian National near Lachevrotière; the levels were then swung over to the latter railway as so to keep as close as possible to the shore of the St. Lawrence. When Cap Rouge was reached the levels were carried up to the Transcontinental line (of the Canadian National), about 120 feet above, and thence across the Quebec Bridge to close on one of our bench marks on the south shore—established several years previously.

Next, a loop line was extended completely around the city of Quebec. Starting from bench mark 755-B in the north abutment of the Quebec Bridge the levels were carried along the track which parallels the river shore till the Champlain Market was reached; St. Pierre street and other city streets were then followed around the end of the city to the Canadian Pacific station and the tracks of this railway and the Canadian National were utilized to reach Cap Rouge where the circuit was closed on bench mark 750-B, one of those on the Three Rivers-Quebec Bridge line. The distance from 755-B around the loop to 750-B was 16·6 miles and the closing error 0·02 foot. The levelling around the loop was, of course, all "double-levelling", that is the levels were run forward from 755-B around to 750-B and then backward over the same, the closure above noted being computed from the mean of the two results. Special pains were taken to establish a sufficient number of thoroughly permanent bench marks in the city and vicinity and in addition a number of previously established Government bench marks were tied in, including the Royal Engineers bench mark, three or four of the Public Works Department, and the Admiralty bench mark on the old Marine and Fisheries building to which the soundings on the Admiralty chart of Quebec harbour are referred.

Branching off from the Quebec loop line at the Canadian Pacific railway station bench mark a line of levels was extended down the Quebec Railway Light and Power Company's (electric) line to the terminus at St. Joachim, this being primarily for the purpose of giving an initial sea-level elevation for the levelling operations of the Quebec Streams Commission along the Ste. Anne river. Also, while the party was in this vicinity they took the opportunity of making a connection between the Naval Service Department's tide gauge at St. Joseph-de-Levis and our main line of precise levels on the south shore of the St. Lawrence river.

On July 16 a new line of levels was started at the Naval Service Department's principal tidal station at Father Point on the lower St. Lawrence, and carried along the Canadian National railway, the only available route, to Rivière-du-Loup where it formed a junction with our old lines from St. Stephen and Edmundston, N.B., and from Levis, Que. The completion of this line will afford an opportunity of placing the levels in New Brunswick and eastern Quebec upon the well established Father Point sea-level datum. Bench marks had previously been established along this line by the Public Works Department and all of these that could be located were connected up; it was found, however, that several had been destroyed, owing to the reconstruction of bridges and culverts.

Levelling was completed at Rivière-du-Loup on August 23 and the party then returned to Quebec and spent the balance of the season—till October 1—working on a line from Quebec towards Chicoutimi. Levelling was suspended at mileage 83·4 from Quebec or 5 miles north of Linton Junction—on the Canadian National railway.

6. Summary of Field Work.

The use of railway motor cars in place of hand-cars for transportation purposes having been thoroughly tried out in previous years, each one of the five parties was so equipped during the season just closed. That is to say, the same hand-cars were used, but the pumping apparatus was replaced by a four-

horsepower gasolene engine. Four of the engines used were made by the Fairmont Gas Engine and Railway Motor Car Company of Fairmont, Minn., and the fifth was a "Silvester" engine of very similar design.

It will be noticed in the detailed description of each party's operations given above, that parties 2, 3, 4 and 5 all discontinued work about the beginning of October. The Vancouver party had completed its program at this time but the other three would have been able to continue for probably another month had it not been for a shortage of funds which necessitated calling in the parties while the weather was still quite favourable for field work.

The mileage run by each leveller is shown in the following table; also the percentage of relevelling; the number of standard bench mark piers built; and the total number of bench marks established, including piers:—

Leveller	Mileage levelled	Relevelling	Piers built	Total Bench Marks established.
D. McMillan	141 (*a*)	10%	34	58
N. H. Smith	182 (*b*)	6%	29	74
A. J. Rainboth	279	8%	39	73
G. F. Dalton	161	6%	4	62
G. E. B. Sinclair	279	12%	11	145
Total	1,042		117	412

(*a*) The mileage credited to D. McMillan represents new work only. Adding to this the rerunning referred to in section 1 of this report—equivalent to 165½ miles of double-levelling—makes a total mileage of 306½ for this party.

(*b*) The 182 miles credited to N. H. Smith consists of 126 miles of double-levelling and 56 miles of single-levelling. All other mileages represent double-levelling.

Line.	On Railway.	Off Railway.	Total.
Colonsay to Saskatoon, Sask	36·9	1·1	38·0
Colonsay to Prince Albert, Sask	98·2	2·6	100·8
Branches at Regina and Dundurn	0·0	2·0	2·0
Vancouver District lines	129·6	51·9	181·5
Irricana to Medicine Hat, Alta	172·9	5·7	178·6
Bassano to 17 miles west of Empress, Alta	100·8	0·0	100·8
Burketon to Midland, Ont	98·6	2·4	101·0
Lindsay to 26 miles east of Howland, Ont	59·5	0·6	60·1
Three Rivers to Quebec Bridge, Que	74·8	4·6	79·4
Quebec Loop-line	15·8	0·8	16·6
Quebec to St. Joachim, Que	25·1	0·8	25·9
Father Point to Rivière-du-Loup, Que	65·2	8·6	73·8
Quebec to 5 miles north of Linton Junction, Que	82·9	0·6	83·5
	960·3	81·7	1,042·0

STANDARDS AND BASE LINE MEASUREMENT

F. A. McDiarmid, Supervisor of Standards, reports as follows on the work carried on under his supervision during the year 1919–20.

1. Comparison of the standard metre nickel bar No. 10239 with the United States standard platinum-iridium metre bars.
2. Intercomparison of the three metre bars Nos. 10239, 10241, and 10241a of the Geodetic Survey of Canada.

3. Determination of the lengths of the five invar fifty-metre tapes of the Geodetic Survey, in July and October.
4. Measuring of the Fort Rupert base line.
5. Standardization of the 100-foot invar tapes of the International Boundary Survey and of the 66-foot tape used in city triangulation.

1. COMPARISON OF THE GEODETIC STANDARD BAR NO. 10239, WITH THE UNITED STATES STANDARD BAR.

The nickel bar No. 10239 which has been used as the standard of length by the Geodetic Survey of Canada was obtained from the National Physical Laboratory at Teddington near London, England, in 1913. It was standardized there and its length as certified to by Prof. R. T. Glasebrook was 1 m. $+26.9\ \mu$ at 0° C. Since this bar was received from the National Physical Laboratory it has been used continually in the standardization of the invar base line tapes, and had not been again compared with any other standard. It was therefore thought wise in order to make sure of the accuracy of the work to have a comparison made of the Canadian Geodetic standard of length with that of the United States Bureau of Standards at Washington.

In May, 1919, the nickel bar No. 10239 was taken to Washington and there through the kindness of Dr. Stratton and Dr. Fischer was compared with the two metre bars known as M_4 and M_{21}. These bars M_4 and M_{21} are of platinum-iridium and were issued by the International Bureau of Standards at Sevres. The United States Bureau has three of these international bars; M_4 and M_{21} are known as the working bars, and the other M_7 the standard bar is kept in a sealed case in a vault. It is only used for the purpose of checking the lengths of the working standards.

The comparator room of the United States Bureau of Standards is in the basement of the Standardization building. This room has a temperature control, whereby the temperature can be raised to any degree necessary. The comparison of the bars was made at 0° Centigrade both bars being packed in melting ice. The two bars to be compared are placed side by side in an ice trough, and adjustments are provided by which the two bars are made parallel and the planes of their graduations horizontal. Two micrometer microscopes a metre apart are mounted on a steel bar which is supported at either end by concrete piers which are separate from the floor. The value of one turn of the micrometer screws of the microscopes is about one hundred microns.

The programme followed in comparing two bars, say M_4 of the United States Bureau of Standards and the Canadian bar No. 10239 was as follows:—

The two bars M_4 with end graduations marked A and B and No. 10239 with end graduations marked 0 and 100 were placed in the ice trough with A end of M_4 adjacent to the 0 end of No. 10239. The trough was then brought under the lines of the microscopes by means of a spiral screw attached to the stand which supports the trough. Bar M_4, was then put under the miscroscope and carefully adjusted for focus and alinement. Then the trough is moved sidewise until bar No. 10239 is under the microscope. The position of this latter bar is adjusted until the graduations are in perfect focus and the longitudinal axis is parallel to the longitudinal axis of the bar M_4. The trough is again moved and M_4 is brought under the microscope. Two observers, one at either microscope, simultaneously read the graduations. Two pairs of readings are made; then the observers change ends, and make two other sets. In this way any personal error of setting is eliminated, in the mean of the four pairs of readings. The trough is now moved and the second bar No. 10239 placed under the microscope; the programme followed with the first bar is repeated

with the second. Then bar M_4 is again placed under the microscope and readings are made. This process is continued until five groups are obtained in the following order: M_4, No. 10239, M_4, No. 10239, and M_4. Then a second group was made in the order No. 10239, M_4, No. 10239, M_4, and No. 10239. One of the bars say M_4 was then reversed in position in the trough and the programme outlined above was repeated. Bar No. 10239 was then reveresd and a full group of readings made, and finally M_4 was again reversed and brought back to its original position, and a fourth group of readings made.

The two bars are then interchanged in their positions in the trough, and a full complement of observations is made, giving in all sixteen groups of comparisons of the two bars, making 640 micrometer readings in all. The following is a sample observation.

Bar	Position
M_4	A..............B
No. 10239	0..............100

	Left Microscope			Right Microscope
	6·600		No. 10239	5·148
	·615			·167
	·638			·183
	·632			·183
Mean	6·621		Mean	5·170
	6·458	M		5·242
	·463			·244
	·458			·249
	·469			·242
Mean	6·462		Mean	5·244
	6·663		No. 10239	5·209
	·658			·212
	·669			·208
	·675			·231
Mean	6·666		Mean	5·215
	6·418	M		5·201
	·418			·206
	·421			·197
	·419			·198
Mean	6·419		Mean	5·200
	6·623		No. 10239	5·176
	·622			·180
	·622			·175
	·628			·185
Mean	6·624		Mean	5·179

These sixteen groups constitute a complete series of observations comparing the two bars M_4 and No. 10239. M_4 was then replaced by the second of the United States working standards M_{21} and a second series comparing M_{21} and No. 10239 was completed. The results of the two comparisons are shown in the following tables.

COMPARISON OF METRE BARS M_{21} AND No. 10239.

Date.	Microscope Readings. Mic. L. Bar M_{21}	Mic. L. Bar No. 10239.	Mic. R. Bar M_{21}	Mic. R. Bar No. 10239.	Difference in Microns. Mic. L.	Difference in Microns. Mic. R.	Difference in Length of Bars in Microns. Total.
1919.					μ	μ	μ
May 17	6·441	6·637	5·222	5·188	19·7	3·6	23·3
	6·374	6·866	5·174	5·438	49·3	−26·1	23·2
	4·968	4·399	4·823	4·025	−57·0	78·3	21·3
	5·238	5·208	4·077	3·837	− 3·0	24·1	21·1
	6·081	6·076	·5905	5·692	− 5·0	21·5	21·0
May 19	7·326	7·247	7·150	6·853	−07·9	29·9	22·0
	10·818	10·990	10·263	10·206	17·2	05·7	22·9
	10·682	10·928	10·142	10·138	24·6	00·4	25·0
	9·545	9·744	9·010	9·000	20·0	01·0	21·0
	9·383	9·503	8·839	8·754	12·0	08·5	20·5
May 20	7·209	7·205	6·652	6·432	− 0·4	23·2	22·8
	7·171	7·235	6·615	6·452	6·4	16·4	22·8
	7·852	7·895	7·284	7·129	4·3	15·6	19·9
	7·959	7·972	7·403	7·202	1·3	20·2	21·5
	7·102	7·238	6·562	6·486	13·6	7·7	21·3
	7·098	7·281	6·560	6·525	18·3	3·3	21·6
	7·567	7·687	7·050	6·911	12·0	12·9	24·9
May 21	8·658	8·832	8·117	8·006	17·4	5·1	22·5
	8·861	8·944	8·304	8·138	8·3	16·6	24·9
May 23	10·494	9·925	9·945	9·164	−57·0	78·6	21·6
	10·038	9·929	9·512	9·173	−10·9	34·1	23·2
	9·250	9·582	9·728	9·822	33·3	− 9·5	23·8
	9·419	9·676	9·904	9·919	25·8	− 1·5	24·3
	9·748	9·823	9·192	9·051	7·5	14·2	21·7
	9·905	9·901	9·349	9·140	−0·4	21·1	20·7
						Mean	22·4

$$\text{Length of } M_{21} = \overset{m}{1} + \overset{\mu}{2{\cdot}5}$$
$$\text{" No. } 10239 = 1 + 24{\cdot}9 \pm {\cdot}21$$

COMPARISONS OF METRE BARS M_4 AND No. 10239.

Date.	Microscope Readings. M_4	No. 10239	M_4	No. 10239	Difference in Microns. L	Difference in Microns. R	Difference in length of Bars in Microns. Total.
1919							
May 21	10·277	10·420	9·806	9·663	14·3	17·4	31·7
	10·342	10·782	9·883	9·991	44·0	−10·9	33·2
May 23	10·422	10·447	10·966	10·665	2·5	30·2	32·7
	9·945	10·021	8·500	8·240	7·6	26·2	33·8
	10·186	10·223	9·717	9·461	3·7	25·8	29·5
	9·945	10·072	8·497	8·298	12·7	20·0	32·7
May 22	10·362	10·017	9·896	9·232	−34·5	67·0	32·5
	10·109	10·342	9·639	9·560	23·3	8·0	31·3
	9·206	9·743	9·747	8·979	53·6	−23·3	30·3
	9·426	9·711	8·979	8·953	28·5	2·6	31·1
	9·782	9·804	9·344	9·038	2·2	30·7	32·9
	9·722	9·687	9·275	8·928	−3·5	34·9	31·4
	9·502	9·858	9·075	9·103	35·6	−02·8	32·6
	9·948	9·941	9·517	9·196	−0·7	32·3	31·6
	10·017	10·142	9·576	9·374	12·5	20·3	32·8
	10·229	10·140	9·784	9·369	−8·9	41·8	32·9
						Mean	32·1

$$\text{Length of } M_4 = \overset{m}{1} - \overset{\mu}{5{\cdot}9}$$
$$\text{" No. } 10239 = 1 \quad 26{\cdot}2 \pm 19$$

The length of No. 10239 as determined from M_4 was $\overset{m}{1}+\overset{\mu}{26\cdot2}\pm\overset{\mu}{\cdot19}$ at 0° C and from M_{21} was $\overset{m}{1}+\overset{\mu}{24\cdot9}\pm\overset{\mu}{\cdot21}$ at 0°C, a difference of $\overset{\mu}{1\cdot3}$. Bars M_4 and M_{21} were then compared with the primary standard bar of the Bureau of Standards and the length of No. 10239 was certified as $\overset{m}{1}+\overset{\mu}{25\cdot8}\pm\overset{\mu}{\cdot21}$ at 0°C. The length as given by the National Physical Laboratory was $\overset{m}{1}+\overset{\mu}{26\cdot9}$ at 0°C or the bar had approximately decreased $1\cdot1\mu$ in five years. In deducing the lengths of the base line tapes this value $\overset{m}{1}+\overset{\mu}{25\cdot8}$ at 0° C has been accepted as the length of the standard bar No. 10239.

2. INTERCOMPARISON OF THE THREE METRE BARS OF THE GEODETIC SURVEY.

The three metre bars of the Geodetic Survey of Canada are described as follows by the International Physical Laboratory.

Bar No. 10239 Nickel.

Description—H–form section, total length about 102·6 cm.
Length of side about 2·5 cm.

Marked ....On front L.I.P. Genève.
On back Nickel No. 10239.

Graduations......The graduations are on the neutral plane of the bar and are at each millimetre from 0 to 100 cm. A millimetre scale divided into tenths is added immediately beyond each end of the fundamental distance 0-100 cm.

Length..........At 0° C, 1000·0269 mm. and its length at t°C is given by the following formula $Lt = Lo\ (1+0{\cdot}00001253t+0{\cdot}00000000521t^2)$. Temperature expressed in hydrogen scale.

Bar No. 10241A Invar.

Description.......H–form section, total length about 102·6 cm., length of side about 2·5 cm.

Marked..........On front; S.I.P. Genève.
On back; 169 Invar 1er Categorie Coulee 3107. No 10241A.

Graduations......The graduations are on the neutral plane of the bar and are at each millimetre from 0 to 100 cm. A millimetre scale divided into tenths is added immediately beyond each end of the fundamental distance 0 to 100 cm.

Length..........At 0° C 999·9676 mm. and its length at t° C is given by the following formula: $Lt=Lo\ (1+0{\cdot}000{,}001{,}28t + 0{\cdot}000{,}000{,}002{,}40t\ )$. Temperature expressed in the hydrogen scale.

Bar No. 10241. 43% Nickel Steel.

Description.......H–form section. Total length about 103 cm. Length of side about 2·25 cm.

Marked..........On front S.I.P. Genève.
On back 133 Acier Nickel 43% Coulee 1186 No. 10241.
R

Graduations......The graduations are on the neutral plane of the bar, and are at each millimetre from 0 to 100 cm. A millimetre scale divided into tenths is added immediately beyond each end of the fundamental distance 0–100 cm.

Length..........At 0° C 999·9806 mm. and length at t° C is given by the following formula Lt = Lo (1 + 0·000,008,02t—0·000,-000,001,38t). Temperature being expressed in the hydrogen scale.

After bar No. 10239 was brought back from Washington, the three bars No. 10239, No. 10241, and No. 10241A were carefully intercompared. The lengths of these three bars had been determined by Dr. Glazebrook at Teddington in 1914, and their lengths are given in the certificates as indicated above.

Bars No. 10239 and No. 10241 were first compared. Each bar was packed in a separate ice trough. The troughs were placed on top of the five metre bar trough, and were carefully adjusted. Two microscopes mounted on two adjacent piers a metre apart were used to read the end graduations of the bars. A complete programme of observations was taken with the bars in the several positions with respect to the observer, following nearly the same programme as used in Washington. However instead of two readings by each observer at either end, five readings were taken, or, in determining the length of a bar with respect to the distance between ten miscroscopes, ten readings were made on either end.

After finishing comparisons of bars Nos. 10239, and 10241 the latter was replaced by No. 10241A and a complete series was made between Nos. 10239 and 10241A. Then to further strengthen the results bar No. 10241 was compared with No. 10241A.

The value of the micrometer screws were determined by observing on the millimetre graduations of bar No. 10239

COMPARISON OF BARS No. 10239 AND No. 10241.

Date.	Readings of Microscopes.				Micrometer diff. in Microns		Difference in Length of Bars at 0° C.
	South.		North				
	No. 10239	No. 10241	No. 10239	No. 10241	South.	North.	
1919					μ	μ	μ
June 4............	1810·1	1794·7	2467·0	2495·5	15·4	28·2	43·6
	1728·8	1718·5	2385·5	2418·2	10·3	32·4	42·7
	1719·6	1679·3	2375·2	2380·0	40·2	5·1	45·3
	1725·2	1674·0	2379·2	2373·9	50·9	− 5·2	45·7
June 5............	1341·5	1329·0	2006·9	2040·6	12·4	33·3	45·7
	1475·4	1497·8	2191·9	2167·0	22·3	24·6	46·9
	1453·9	1438·8	2123·7	2154·3	15·0	30·2	45·2
	1476·1	1462·2	2146·3	2178·9	13·8	32·2	46·0
	1469·7	1472·9	2190·2	2139·9	−3·2	49·7	46·5
	1634·2	1605·9	2304·7	2323·6	28·1	18·7	46·8
	1537·9	1503·8	2221·0	2210·3	33·9	10·6	44·5
	1522·4	1486·7	2192·8	2202·5	35·5	9·6	45·1
	1526·4	1501·7	2197·2	2218·1	24·9	20·7	45·6
	1502·7	1541·7	2218·9	2210·9	38·8	7·9	46·7
	1526·2	1476·7	2195·2	2191·1	49·2	−4·0	45·2
	1421·6	1411·3	2089·0	2125·2	10·2	35·7	45·9
						Mean	45·5±20

COMPARISON OF BARS No. 10241 AND No. 10241A.

Date.	Readings of Microscopes.				Micrometer diff. in Microns.		Difference Length of Bars at 0° C.
	South.		North.				
	No. 10241	No. 10241A	No. 10241	No. 10241A	South.	North.	
1919					μ	μ	μ
June 10............	1507·9	1505·3	2246·9	2248·5	2·6	1·6	4·2
	1450·9	1444·5	2190·1	2188·8	6·3	−1·3	5·0
	1473·0	1469·5	2212·0	2213·5	3·5	1·5	5·0
	1452·6	1448·4	2191·7	2191·8	4·2	0·1	4·3
	1474·3	1471·4	2212·9	2216·0	2·9	3·1	6·0
	1454·2	1452·6	2191·2	2195·3	1·6	4·1	5·7
	1435·0	1429·0	2173·0	2171·7	6·0	−1·3	4·7
	1419·8	1476·9	2158·0	2159·6	2·9	1·6	4·5
	1415·0	1410·3	2150·7	2152·1	4·7	1·4	6·1
	1413·0	1410·2	2150·7	2152·8	2·8	2·1	4·9
	1400·5	1399·6	2137·9	2142·5	0·9	4·6	5·5
	1372·2	1375·7	2111·0	2119·6	−3·5	8·5	5·0
June 9.............	1460·8	1460·8	2196·2	2200·8	0·0	4·5	4·5
	1456·9	1452·8	2195·2	2195·1	4·1	−0·1	4·0
	1472·1	1472·8	2208·3	2214·5	−0·7	6·0	5·3
	1453·1	1453·5	2188·9	2194·4	−0·4	5·5	5·1
						Mean	4·9+·10

COMPARISON OF BARS No. 10239 AND No. 10241A.

Date.	Readings of Microscopes.				Micrometer diff. in Microns.		Difference in Length of Bars at 0° C.
	South.		North.				
	No. 10239.	No. 10241A	No. 10239	No. 10241A	South.	North.	
1919					μ	μ	μ
June 6.............	1514·8	1473·1	2187·3	2196·0	41·7	8·7	50·4
	1593·9	1590·3	2270·0	2315·1	3·6	44·6	48·2
	1469·9	1469·3	2153·0	2202·2	0·6	48·7	49·3
	1484·4	1444·5	2165·3	2173·5	39·9	8·2	48·1
June 7.............	1375·8	1345·3	2066·2	2085·5	30·5	19·2	49·7
	1495·6	1443·5	2184·8	2183·3	52·1	−1·5	50·6
	1376·0	1373·5	2065·6	2114·0	2·5	47·9	50·4
	1381·2	1381·2	2069·9	2120·8	0·0	50·4	50·4
	1373·3	1373·1	2082·7	2112·0	0·2	48·6	49·0
	1364·8	1363·3	2053·6	2104·1	1·5	50·0	51·5
	1360·0	1364·3	2048·9	2102·8	−4·3	53·3	49·0
	1372·4	1368·3	2061·7	2106·8	4·1	45·0	49·1
June 9.............	1367·8	1364·0	2058·8	2105·1	3·8	45·8	49·6
	1360·1	1363·0	2052·1	2105·4	−2·9	52·7	49·8
	1364·2	1361·3	2055·2	2103·7	2·9	47·9	50·8
	1364·7	1363·3	2056·4	2105·6	1·4	48·6	50·0
						Mean	49·8±·15

Difference in lengths of bar No. 10239 and bar No. 10241 $= \overset{\mu}{45\cdot5} \pm 20$

" " " " No. 10241A $= \overset{\mu}{49\cdot8} \pm 15$

" " No. 10241 " No. 10241A $= \overset{\mu}{4\cdot9} \pm 10$

Length of bar No. 10239 at 0° C. $= \overset{m}{1} + \overset{\mu}{25\cdot8}$

" " No. 10241A at 0° C. $= \overset{m}{1} - \overset{\mu}{24\cdot2}$

" " No. 10241 at 0° C. $= 1 - 19\cdot5$

According to certificates issued by National Physical Laboratory.

Length of bar No. 10239 at 0° C. $= \overset{m}{1} + \overset{\mu}{26\cdot9}$

" " No. 10241A at 0° C. $= \overset{m}{1} - \overset{\mu}{32\cdot4}$

" " No. 10241 at 0° C. $= \overset{m}{1} - \overset{\mu}{19\cdot4}$

Or bar No. 10239 has shortened 1·1μ, while No. 10241A has lengthened by 8·2μ, and No. 10241 has shortened by 0·1μ

The change in length of the standard nickel bar No. 10239 from 1m.$+26\cdot 9\mu$ to 1m.$+25\cdot 8\mu$ means a difference of approximately one in a million, in a period of five years. It is unfortunate that there have not been frequent intercomparisons of the three metre bars. It will be the future policy to have these bars intercompared frequently.

3. DETERMINATION OF LENGTHS OF INVAR FIFTY-METRE TAPES.

As formerly the length of the five-metre bar was determined from the standard bar No. 10239. The length of the five-metre comparator is determined in terms of the length of the five-metre bar in a solution of melting ice, and in readings of the micrometers. The trough containing the metre bar is then mounted on top of the five-metre ice trough and the length of the five-metre comparator is again determined, this time in terms of the length of the metre bar and various micrometer readings. In several cases discrepancies arose which seemed difficult to explain. Sometimes it would appear as if the length of the five-metre bar was changing. Finally it was discovered that the erroneous readings on the five-metre bar arose when the trough containing the metre bar was resting on top of the five-metre ice trough. The explanation suggested is that the extra weight, about one hundred pounds induced a flexure and shortened the five-metre bar about seven or eight microns. As soon as the metre trough was removed the five-metre bar took up its original length. All readings on the five-metre bar are now being made without the one-metre trough on top.

Another seeming inconsistency showed itself in the five-metre bar observations. When the bar is first put in the ice solution, the temperature of the bar gradually falls and the length decreases. The temperature will not go below 0°C, yet some observations have shown that the length seems to decrease below the length at 0° C. This matter was mentioned to Prof. Gilchrist of Toronto University, and while he was not prepared to give a decided opinion, he felt that an alloy such as steel might behave in such a manner; that is, it would continue to decrease in length after the temperature reached 0° C, and after a time it would again increase until a constant length was reached. It is the policy in the standards work of the Geodetic Survey to have the bars in melting ice for at least twenty-four hours before being used. When this is done, there is no trouble with varying lengths of the five-metre bar.

One condition that must be rigorously adhered to is that the five-metre bar must not be changed in its position between the time when it is standardized from the metre bar, and the time when it is used to determine the length of the fifty-metre comparator. A programme which was followed the past season, and which gave splendid results is to determine the length of the five-metre bar from the metre bar in the forenoon and the length of the fifty-metre reference tape from the length of the five-metre bar in the afternoon. In the first half of the day if everything goes satisfactorily twelve determinations of the length of the five-metre bar can be obtained, and in the second half twelve determinations of the fifty-metre tape. This programme allows no opportunity for the five-metre bar to shift its position in the trough.

Reference has been made to the mounting of the one-metre bar over the five-metre bar. In order to avoid the necessity of adding this extra load, a new car to carry the metre bar and trough is being made. This new equipment along with five new micrometer microscopes will make the Standards Building of the Geodetic Survey of Canada completely equipped for doing excellent work in establishing the length of tape lines from the primary standards. These five new microscopes are being built in London by Instruments Limited.

The lengths of the five invar tapes, the two reference and three field tapes were determined in June and July and in September and October, before and after measuring the Fort Rupert base line.

The length of the five-metre bar from the June–July observations was 4·9999410 metres, and the length from the September observations was 4·9999486 metres, a seeming change of 7·6 microns. This difference is no doubt due to the slightly different positions on which the bar was placed in the ice trough.

The length of the reference tape No. 4252 from the July observations was 50·000414 metres, and from the October observations was 50·000409 metres. The length of the other reference tape No. 13814 in July and October was 50·000296 and 50·000304 metres respectively. The results show a shortening of five microns in tape No. 4252 and lengthening of eight microns in No. 13814, and indicate that both these tapes retained their length throughout the summer. This was to be expected as they were left hanging in a double catenary in the Standards Building. These lengths are all deduced for the temperature 16°·5 C.

The deduced lengths of the three field tapes Nos. 3139, 3140 and 3141 are for the July and October determinations respectively as follows: 49·999480 and 49·999420 metres, 50·000063 and 50·000056 metres, 50·000410 and 50·000300 metres. The means of these two values for each tape were taken as the length to be applied to determine the length of the base line. It will be seen that tape No. 3139 decreased in length 60 microns, tape 3140 decreased 7 microns and tape 3141 decreased 110 microns. These changes show the absolute necessity of frequently standardizing the tapes used in measuring primary base lines. The tapes were used with the greatest possible care both in standardizing and in the field, yet one of them changed its length by one part in 500,000.

4. MEASUREMENT OF FORT RUPERT BASE LINE AT THE NORTHEAST ANGLE OF VANCOUVER ISLAND.

The Fort Rupert base line at the north-east corner of Vancouver island is about 5·9 miles long and passes through a densely wooded country. Excepting the parts covered by two short swamps the whole length of the base line was in the months of July, August and September, hard and dry. A description of the work of clearing and posting this base has been made by Mr. K. H. Robb. A line of precise levels run over the tops of the posts gave several large differences of elevations between adjacent 50-metre posts.

Each kilometre was measured four times, forward and backward with two tapes. Probably a word of explanation in the use of the tape would be of interest. The tape is placed in position under a tension of 15 kilogrammes over frictionless pulleys at either end and at the centre is run over a frictionless race. This race is so placed that a straight line across the end posts just touches the top of the race. The graduations on the tape do not go all the way across the tape, but only part way. The tape is so placed that the graduations at the edge of the tape are touching the copper strips which are placed on top of the posts to carry the marks. When the tape is adjusted one of the observers moves, say pulls, the tape slowly till the graduation at the rear end comes just to the mark on the copper plate; then he calls "mark" to the observer at the other end, and the latter makes a mark on the plate opposite the graduation at his end of the tape. This process is repeated twice to check the mark carefully. Thermometers attached one metre inside the graduations at the ends of the tape give its temperature. In this way the distance between the posts, say 0 to 20, is measured. At post 20 the observers change ends; the thermometers also are transfered. The same observer continues to move the tape in the same direction, but now instead of pulling he is pushing. The length from post 20 to 0 is next measured. It was interesting to note the difference in the determinations as made when pushing or pulling the tape. These differences will be seen in the tables showing the results of the several kilometres of the base. A second tape was used in exactly the same way. The mean of the "push" and "pull" determinations

was taken as the length of the kilometre from the tape. The length of a single kilometre as determined with the different tapes nearly always agreed closer than one millimetre. Below is a table showing the length of the different kilometres as determined with the several tapes uncorrected for elevations or elongation of tapes due to differences of elevation of the supports.

UNCORRECTED LENGTHS OF SECTIONS SHOWING FORWARD AND BACKWARD MEASUREMENTS.

Length of Section.				Difference.	Mean of	Difference of Length of Section.
Section.	Tape.	Forward	Backward.	F–B	F–B	
		m.	m.	mm.	m.	mm.
0–20	3139	999·891460	999·892880	−1·420	999·892170	
0–20	3140	999·896290	999·890200	+6·090	999·893245	1·075
20–40	3140	1000·005650	1000·008630	−2·980	1000·007140	
20–40	3141	1000·007000	1000·007560	−0·560	1000·007280	0·140
40–60	3141	999·972640	999·971760	0·880	999·972200	
40–60	3139	999·976760	999·975390	1·350	999·976075	3·875
60–80	3139	999·891710	999·892420	−0·710	999·892065	
60–80	3140	999·893160	999·892990	0·170	999·893075	1·010
80–100	3141	999·916572	999·913756	2·816	999·915164	
80–100	3140	999·914029	999·912240	0·789	999·913134	2·030
100–120	3141	1000·031820	1000·026080	5·740	1000·028950	
100–120	3139	1000·032000	1000·027430	4·570	1000·029715	0·765
120–140	3139	1000·067020	1000·063900	3·120	1000·065460	
120–140	3140	1000·066990	1000·062890	4·100	1000·064940	0·520
140–160	3141	999·968820	999·962990	5·830	999·965905	
140–160	3140	999·966609	999·964041	2·568	999·965325	0·781
160–180	3139	1000·080950	1000·077020	3·930	1000·078985	
160–180	3141	1000·082500	1000·077810	4·690	1000·080155	1·170
180–191	3139	550·285023	550·281953	3·070	550·283488	
180–191	3140	550·284041	550·282301	1·740	550·283171	0·317

The following table gives the result for the various sections of the base line with all corrections applied and reduced to sea-level.

Section.	Uncorrected Lengths.	Inclination.	Elongation.	Correction Sea Level.	Corrected Lengths.
	Metres.	Metres.	Metres.	Metres.	Metres.
0–20	999·892707	−0·942232	+0·002486	−0·004940	998·948021
20–40	1000·007210	−0·027853	+0·000018	−0·004240	999·975135
40–60	999·974138	−0·073095	+0·000037	−0·003765	999·897315
60–80	999·892570	−0·169490	+0·000123	−0·002618	999·720585
80–100	999·914149	−0·290413	+0·000184	−0·002288	999·621631
100–120	1000·029332	−0·424108	+0·000489	−0·003160	999·602553
120–140	1000·065200	−0·234441	+0·000282	−0·003221	999·827820
140–160	999·965615	−0·192448	+0·000097	−0·002405	999·770859
160–180	1000·079570	−0·298624	+0·000194	−0·003904	999·777236
180–191	550·283329	−0·203018	+0·000140	−0·003497	550·076954
				Length of Base:	9547·218109

Large differences of elevations between posts occurred at several places along ths base line. This condition naturally raised the question, as to whether the equation of the catenary adopted for a tape supported at the ends and centre, held when the end supports were at very different elevations. There was no means available in the field to test this condition, but on returning from Fort Rupert, a tower was erected on the grounds of the Geodetic Survey and some results were obtained; weather conditions prevented complete determinations, but enough were secured to show that some correction for elongation must be applied when the difference of elevations exceeds twelve feet. In the coming spring it is the intention to make a full and complete test.

Considered from a theoretical standpoint, if L be the length of a tape, h the difference in altitude of its ends, W the weight in grammes per metre, and T the tension in grammes the elongation of a tape supported at the centre is given by the formula $E = A^2 \frac{L^3}{48} \left(\frac{h}{L}\right)^2 + \frac{1}{8} L \left(\frac{h}{L}\right)^4$, where $A = \frac{W^2}{T}$. The elongation for a fifty metre invar tape supported at the centre for various differences of elevation is given in the following table.

CORRECTIONS IN LENGTHS OF TAPE DUE TO DIFFERENCES IN HEIGHT OF SUPPORTS.

Difference of Heights of Supports in Metres.	Corrections.		
	$\frac{1}{48} A^2 L^3 \left(\frac{h}{L}\right)^2$	$\frac{1}{8} L \left(\frac{h}{L}\right)^4$	Total.
0	0·000	0·000	0·000
1	0·003	0·001	0·004
1·5	0·007	0·005	0·012
2·0	0·013	0·016	0·029
2·5	0·019	0·039	0·058
3·0	0·029	0·081	0·110
3·5	0·040	0·150	0·190
4·0	0·051	0·256	0·307
4·5	0·065	0·410	0·475
5·0	0·080	0·625	0·705
5·25	0·088	0·759	0·847
5·50	0·096	0·915	1·011
5·75	0·105	1·093	1·198
6·0	0·115	1·296	1·411

The correction for inclination of the tapes due to differences of elevation of the end supports is derived as follows. If x be the difference of elevations in metres of the end supports of a fifty-metre tape the horizontal distance between supports is:

$$\left\{50^2 - x^2\right\}^{\frac{1}{2}} \text{ metres or } 50\left\{\frac{1-x^2}{2,500}\right\}^{\frac{1}{2}}, \text{ or } 50\left\{\frac{1-x^2}{5,000} - \frac{1}{8}\frac{x^4}{50^4} - - -\right\}, \text{ or}$$

$$\left\{50 - \frac{x^2}{100} - \frac{x^4}{1,000,000}\right\} \text{ metres}$$

Hence the correction for inclination $= \left\{\frac{x^2}{100} + \frac{x^4}{1,000,000}\right\}$ metres since terms beyond the third are of vanishing quantity.

5. STANDARDIZATION OF 100-FOOT BOUNDARY SURVEY TAPE, AND 66-FOOT TAPE USED IN CITY TRIANGULATION.

The comparator of the Standards building is divided into ten equal parts of five metres each, and the last five metre space at the north end is divided into parts of one metre each by means of piers.

One hundred feet is equal to 30·48 metres nearly or one hundred feet is equivalent to six lengths of five metres and the fraction ·48 of a metre. To obtain two microscopes 0·48 of a metre apart, an aluminium frame was made to reach across one of the metre spaces. On this frame was mounted a microscope near the centre and so placed that when the zero division of the one metre bar is under the microscope at the metre pier the microscope at the centre is over the 48 cm. division.

In May boundary survey tapes Nos. 13280 and 13283, after being repaired by Instruments Limited, were standardized and found as follows:—

Tape 13280 at 16°. 7 C or 62° F, 99·9901 ft.
Tape 13283 at 16°. 7 C or 62° F, 99·9833 ft.

In October these tapes and two others were again standardized and gave lengths as follows.

Tape 13280 62° F 99·9890 ft.
Tape 13283 62° F 99·9846 ft.
Tape 13281 62° F 99·9845 ft.
Tape 13282 62° F 99·9904 ft.

Sixty-six feet is equal to 20·1168 metres or four lengths of the five meter bar and a distance equal to 11·68 cm. A fine graduation was placed on the tape at the 20-metre length, and this part of the tape was measured in terms of lengths of the five-metre bar. The small length of 11·68 cm. was measured on a measuring engine.

The length of the tape at 16°·2 C is 65·9983 feet.

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Department of the Interior
GEODETIC SURVEY OF CANADA
MAP SHOWING
PROGRESS OF TRIANGULATION
TO MARCH 31, 1920
BY THE
GEODETIC SURVEY OF CANADA
NOEL J. OGILVIE, Superintendent
Scale, 100 miles to one inch
LEGEND
TRIANGULATION COMPLETED
TRIANGULATION BEGUN
HUDSON BAY
PACIFIC OCEAN
ATLANTIC OCEAN
NORTH WEST TERRITORIES
YUKON
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
LABRADOR
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
GULF OF ST LAWRENCE
HUDSON STRAIT
James Bay
Victoria Island
GREAT BEAR LAKE
GREAT SLAVE LAKE
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
ONTARIO
QUEEN CHARLOTTE ISLANDS
VANCOUVER
UNITED STATES

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- - - - - - - Precise Levelling, Not Published.